SEISMIC HAZARD ZONE REPORT 102

SEISMIC HAZARD ZONE REPORT FOR THE JUNIPER HILLS 7.5-MINUTE QUADRANGLE, LOS ANGELES COUNTY, CALIFORNIA

2003

DEPARTMENT OF CONSERVATION
California Geological Survey

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EXECUTIVE SUMMARY

This report summarizes the methods and sources of information used to prepare the Seismic Hazard Zone Map for the Juniper Hills 7.5-Minute Quadrangle, Los Angeles County, California. The map displays the boundaries of zones of required investigation for liquefaction and earthquake-induced landslides over an area of approximately 31 square miles at a scale of 1 inch = 2,000 feet.

The Juniper Hills Quadrangle lies in northeastern Los Angeles County where the San Gabriel Mountains abut the Mojave Desert. The area is 15 miles southeast of Palmdale and 32 miles northeast of the Los Angeles Civic Center. The San Andreas Fault Zone cuts across the area as a series of linear hills and trough-like valleys. The San Gabriel Mountains rise abruptly above broad, north-sloping alluvial fans and low hills that underlie the rural community of Juniper Hills with its scattered rural residences and small ranches. Part of the community of Pearblossom is within the northeastern corner. The California Aqueduct also crosses the northeastern corner. The Angeles National Forest covers about half of the quadrangle. Access to the region is via Pearblossom Highway (State Highway 138).

The map is prepared by employing geographic information system (GIS) technology, which allows the manipulation of three-dimensional data. Information considered includes topography, surface and subsurface geology, borehole data, historical ground-water levels, existing landslide features, slope gradient, rock-strength measurements, geologic structure, and probabilistic earthquake shaking estimates. The shaking inputs are based upon probabilistic seismic hazard maps that depict peak ground acceleration, mode magnitude, and mode distance with a 10 percent probability of exceedance in 50 years.

In the Juniper Hills Quadrangle the liquefaction zone is typically associated with washes and the alluvial aprons between the San Andreas Fault Zone and Fort Tejon Road where, historically, ground water has been within 40 feet of the surface. Landslides are rare in the quadrangle. Crystalline rock that is resistant to landsliding underlies much of the elevated terrain. Only the steepest slopes and cliff-like features are zoned. This results in 9 percent of the evaluated portion of the quadrangle lying within the earthquake-induced landslide hazard zone for the Juniper Hills Quadrangle.

How to view or obtain the map

Seismic Hazard Zone Maps, Seismic Hazard Zone Reports and additional information on seismic hazard zone mapping in California are available on the California Geological Survey's Internet page: http://www.consrv.ca.gov/CGS/index.htm

Paper copies of Official Seismic Hazard Zone Maps, released by CGS, which depict zones of required investigation for liquefaction and/or earthquake-induced landslides, are available for purchase from:

BPS Reprographic Services
149 Second Street
San Francisco, California 94105
(415) 512-6550

Seismic Hazard Zone Reports (SHZR) summarize the development of the hazard zone map for each area and contain background documentation for use by site investigators and local government reviewers. These reports are available for reference at CGS offices in Sacramento, San Francisco, and Los Angeles. **NOTE: The reports are not available through BPS Reprographic Services.**

INTRODUCTION

The Seismic Hazards Mapping Act (the Act) of 1990 (Public Resources Code, Chapter 7.8, Division 2) directs the California Department of Conservation (DOC), Division of Mines and Geology (DMG) [now called California Geological Survey (CGS)] to delineate seismic hazard zones. The purpose of the Act is to reduce the threat to public health and safety and to minimize the loss of life and property by identifying and mitigating seismic hazards. Cities, counties, and state agencies are directed to use the seismic hazard zone maps in their land-use planning and permitting processes. They must withhold development permits for a site within a zone until the geologic and soil conditions of the project site are investigated and appropriate mitigation measures, if any, are incorporated into development plans. The Act also requires sellers (and their agents) of real property within a mapped hazard zone to disclose at the time of sale that the property lies within such a zone. Evaluation and mitigation of seismic hazards are to be conducted under guidelines adopted by the California State Mining and Geology Board (SMGB) (DOC, 1997). The text of this report is on the Internet at http://gmw.consrv.ca.gov/shmp/SHMPsp117.asp

The Act directs SMGB to appoint and consult with the Seismic Hazards Mapping Act Advisory Committee (SHMAAC) in developing criteria for the preparation of the seismic hazard zone maps. SHMAAC consists of geologists, seismologists, civil and structural engineers, representatives of city and county governments, the state insurance commissioner and the insurance industry. In 1991 SMGB adopted initial criteria for delineating seismic hazard zones to promote uniform and effective statewide implementation of the Act. These initial criteria provide detailed standards for mapping regional liquefaction hazards. The Act also directed CGS to develop a set of probabilistic seismic maps for California and to research methods that might be appropriate for mapping earthquake-induced landslide hazards.

In 1996, working groups established by SHMAAC reviewed the prototype maps and the techniques used to create them. The reviews resulted in recommendations that 1) the process for zoning liquefaction hazards remain unchanged and 2) earthquake-induced landslide zones be delineated using a modified Newmark analysis.

This Seismic Hazard Zone Report summarizes the development of the hazard zone map. The process of zoning for liquefaction uses a combination of Quaternary geologic mapping, historical ground-water information, and subsurface geotechnical data. The process for zoning earthquake-induced landslides incorporates earthquake loading, existing landslide features, slope gradient, rock strength, and geologic structure. Probabilistic seismic hazard maps, which are the underpinning for delineating seismic hazard zones, have been prepared for peak ground acceleration, mode magnitude, and mode distance with a 10 percent probability of exceedance in 50 years (Petersen and others, 1996) in accordance with the mapping criteria.

This report summarizes seismic hazard zone mapping for potentially liquefiable soils and earthquake-induced landslides in the Juniper Hills 7.5-Minute Quadrangle.

SECTION 1
LIQUEFACTION EVALUATION REPORT

Liquefaction Zones in the Juniper Hills 7.5-Minute Quadrangle, Los Angeles County, California

By
Elise Mattison, Ralph C. Loyd, and Cynthia L. Pridmore

California Department of Conservation
California Geological Survey

PURPOSE

The Seismic Hazards Mapping Act (the Act) of 1990 (Public Resources Code, Chapter 7.8, Division 2) directs the California Department of Conservation (DOC), Division of Mines and Geology (DMG) [now called California Geological Survey (CGS)] to delineate Seismic Hazard Zones. The purpose of the Act is to reduce the threat to public health and safety and to minimize the loss of life and property by identifying and mitigating seismic hazards. Cities, counties, and state agencies are directed to use seismic hazard zone maps developed by CGS in their land-use planning and permitting processes. The Act requires that site-specific geotechnical investigations be performed prior to permitting most urban development projects within seismic hazard zones. Evaluation and mitigation of seismic hazards are to be conducted under guidelines adopted by the California State Mining and Geology Board (SMGB) (DOC, 1997). The text of this report is on the Internet at http://gmw.consrv.ca.gov/shmp/SHMPsp117.asp

Following the release of DMG Special Publication 117 (DOC, 1997), agencies in the Los Angeles metropolitan region sought more definitive guidance in the review of geotechnical investigations addressing liquefaction hazards. The agencies made their request through the Geotechnical Engineering Group of the Los Angeles Section of the American Society of Civil Engineers (ASCE). This group convened an implementation committee under the auspices of the Southern California Earthquake Center (SCEC). The committee, which consisted of practicing geotechnical engineers and engineering geologists, released an overview of the practice of liquefaction analysis, evaluation, and mitigation techniques (SCEC, 1999). This text is also on the Internet at: http://www.scec.org/

This section of the evaluation report summarizes seismic hazard zone mapping for potentially liquefiable soils in the Juniper Hills 7.5-Minute Quadrangle. Section 2 (addressing earthquake-induced landslides) and Section 3 (addressing potential ground shaking) complete the report, which is one of a series that summarizes production of similar seismic hazard zone maps within the state (Smith, 1996). Additional information on seismic hazards zone mapping in California is on CGS's Internet web page: http://www.consrv.ca.gov/CGS/index.htm

BACKGROUND

Liquefaction-induced ground failure historically has been a major cause of earthquake damage in southern California. During the 1971 San Fernando and 1994 Northridge earthquakes, significant damage to roads, utility pipelines, buildings, and other structures in the Los Angeles area was caused by liquefaction-induced ground displacement.

Localities most susceptible to liquefaction have loose, water-saturated, granular sediment within 40 feet of the ground surface. These geological and ground-water conditions exist in parts of southern California, most notably in some densely populated valley regions and alluviated floodplains. In addition, the potential for strong earthquake ground shaking is high because of the many nearby active faults. The combination of these factors constitutes a significant seismic hazard in the southern California region, including areas in the Juniper Hills Quadrangle.

METHODS SUMMARY

Characterization of liquefaction hazard presented in this report requires preparation of maps that delineate areas underlain by potentially liquefiable sediment. The following were collected or generated for this evaluation:

- Geologic maps that provide an accurate representation of the spatial distribution of Quaternary deposits in the study area
- Ground-water maps that show historically shallowest ground-water levels
- Geotechnical borehole logs that provide data on the engineering properties of Quaternary deposits
- Probabilistic-based ground shaking intensity maps

The data collected for this evaluation were processed into a series of geographic information system (GIS) layers using commercially available software. The liquefaction zone map was derived from a synthesis of these data and according to criteria adopted by the SMGB (DOC, 2000).

SCOPE AND LIMITATIONS

Evaluation for potentially liquefiable soils generally is confined to areas covered by Quaternary (less than about 1.6 million years) sedimentary deposits. Such areas within the Juniper Hills Quadrangle consist mainly of alluviated valleys. CGS's liquefaction hazard evaluations are based on information on earthquake ground shaking, surface and subsurface lithology, geotechnical soil properties, and ground-water depth, which is gathered from various sources. Although selection of data used in this evaluation was rigorous, the quality of the data used varies. The State of California and the Department of Conservation make no representations or warranties regarding the accuracy of the data obtained from outside sources.

Liquefaction zone maps produced by CGS are intended to prompt more detailed, site-specific geotechnical investigations, as required by the Act. These maps identify areas where there is potential for liquefaction. They do not predict the amount or direction of liquefaction-related ground displacements, or the amount of damage to facilities that may result from liquefaction. Factors that control liquefaction-induced ground failure are the extent, depth, density, and thickness of liquefiable materials, depth to ground water, rate of drainage, slope gradient, proximity to free faces, and intensity and duration of ground shaking. These factors must be evaluated on a site-specific basis to assess the potential for ground failure at any given project site.

Information developed in the study is presented in two parts: physiographic, geologic, and hydrologic conditions in PART I, and liquefaction and zoning evaluations in PART II.

PART I

PHYSIOGRAPHY

Study Area Location and Physiography

The Juniper Hills Quadrangle covers about 62 square miles in northeastern Los Angeles County along the boundary between the San Gabriel Mountains and the Mojave Desert. The center of the area is 15 miles southeast of Palmdale and 32 miles northeast of the Los Angeles Civic Center. The entire quadrangle consists of unincorporated Los Angeles County land. The San Gabriel Mountains rise abruptly to the south, above broad alluvial fans and low hills that underlie the rural community of Juniper Hills, which consists of scattered residences and small ranches. Out on the Mojave Desert, part of the community of Pearblossom is at the northeastern corner of the quadrangle. The boundary of the Angeles National Forest cuts across the quadrangle in a stair-step fashion from the northwestern corner to the middle of the eastern boundary. National forest land covers about half of the quadrangle. Only about 52 percent (32 square miles) of the quadrangle was evaluated for zoning.

The primary geologic element within the quadrangle is the northwest-striking San Andreas Fault Zone. It is manifest as a series of linear hills and trough-like valleys within the San Andreas Rift. Several canyons dissect the steep mountain front and cross the sloping terrain under Juniper Hills. The northward-sloping alluvial fan and scattered hills are typically brushy, arid desert. In the part of the quadrangle subject to development the steepest slopes are generally along the margins of the canyons. The highest elevation in the quadrangle is along the crest of Pleasant View Ridge at 7,983 feet. The lowest elevation, less than 3,200 feet, occurs along the northern edge of the quadrangle.

Access to the study area is via Pearblossom Highway (State Highway 138), which is just north of the quadrangle. Fort Tejon Road and other county roads, especially 106th Street East and 131st Street East also provide access. A segment of the California Aqueduct crosses the northeastern corner of the area.

GEOLOGY

Bedrock and Surficial Geology

The geologic map used as background geology for the Juniper Hills Quadrangle (Plate 1.1) was prepared from three sources. Detailed geologic strip maps of the San Andreas Fault Zone, including the segment that traverses the Juniper Hills Quadrangle, were prepared by Barrows and others (1985, Plates 1F and 1G). Ponti (1980) and Ponti and Burke (1980) mapped the Quaternary geology of eastern Antelope Valley and vicinity, including the northern part of the Juniper Hills Quadrangle. The Southern California Areal Mapping Project (SCAMP) provided geologic maps from both of these sources in digital form. Also, part of a geologic map by Dibblee (2002) was digitized by CGS to fill in the portion of the Juniper Hills Quadrangle south of the detailed strip map developed by Barrows and others (1985). Other important maps and reports referenced by staff during the course of this study include Barrows (1980; 1987).

Note that Plate 1.1 reflects no CGS attempt to modify original mapping or resolve border differences among the various geologic maps. CGS staff addressed such differences only during construction of the liquefaction zone map using techniques and tools such as topography, aerial photography, satellite imagery, and limited fieldwork.

As can be noted on Plate 1.1, only about 30 percent of the quadrangle is covered by alluvial deposits of Quaternary age. These Pleistocene through Holocene surficial deposits are summarized in Table 1.1 and discussed below. The remaining area consists of sedimentary and igneous and metamorphic rocks exposed in the San Gabriel

Mountains. The bedrock units are discussed in the earthquake-induced landslide portion (Section 2) of this report.

Map Unit			Environment of Deposition	Age
Ponti and Burke (1980)	**Barrows and others (1985)**	**Dibblee (2002)**		
Q6, Q7	**Qal, Qbl, Qblm, Qf, Qcp, Qpa, Qsw, Qsc, Qpa**	**Qa, Qg**	alluvial fan, wash, ponds, terrace colluvial aprons	latest Pleistocene and Holocene
Q4, Q5	**Qoa, Qof, Qoc**	**Qoa, Qos**	alluvial fan, wash, colluvial aprons	late Pleistocene
Q1, Q2, Q3	**Qoa, Qof, Qoc**	**Qoa, Qos**	alluvial fan, wash, colluvial aprons	late Pleistocene
	Harold Fm. (Qh)	**Qoa, Qos**	alluvial fan, wash, colluvial aprons, playas	Pleistocene

Table 1.1. Correlation of geologic map units used in the Juniper Hills Quadrangle.

In short, Ponti and Burke (1980) mapped the Quaternary units based mainly on relative age (Q1-Q7) and grain size (f=fine, m=medium, and c=coarse). Barrows and others (1985) divided Quaternary deposits mainly on the basis of older and younger deposits (for example, Qoa, Qal) and environment of deposition (for example, Qsc, Qf, Qpa for stream channel, alluvial fan, and pond deposits). In the Juniper Hills Quadrangle, Dibblee (2002) divides Quaternary deposits on the basis of older and younger deposits (Qa and Qoa) and whether young Quaternary deposits are active stream deposits (Qg) or valley alluvium (Qa).

Quaternary deposits exposed in the Antelope Valley

The oldest Quaternary unit mapped by Ponti and Burke (1980) consists of weakly consolidated, uplifted, and moderately to severely dissected Pleistocene alluvial fan deposits (Q1, Q2, Q3). These deposits occur in small, isolated patches generally along the base of the San Gabriel Mountains. Soils on these units are moderately to well developed with well formed horizons and clay accumulations and are distinctly reddish-brown. The "B" profile ranges from 50 cm in the youngest deposits (Q3) to 2 m in the oldest (Q1). The units are mapped largely on the basis of the distribution of the units, from a close relationship between present day topography and clast sources (Q3) to no apparent relationships (Q1). In the Juniper Hills Quadrangle these older deposits are undifferentiated (Q1-3). Generally, Q1, Q2, and Q3 of Ponti and Burke (1980) correlate with the late Pleistocene units mapped in the San Andreas Rift Zone by Barrows and others (1985), namely the Sandberg Formation, Nadeau Gravel, and Shoemaker Gravel (not all present in the Juniper Hills Quadrangle). Q1-3 also correlate with parts of the undifferentiated older Quaternary deposits (Qoa) of Dibblee (2002).

About half of the Antelope Valley portion of the Juniper Hills Quadrangle (northeastern corner of the quadrangle) is covered by late Pleistocene sediments (Q4). Ponti and Burke (1980) describe this unit, along with small patches of slightly younger Q5, as unconsolidated, uplifted, and slightly dissected alluvial fan deposits. The two units are related because of similarities in topographic expression and soil development. The materials are generally coarse and have moderately developed soils and clay accumulations in B profiles that are less than 50 cm with sound, but oxidized, granitic clasts. Color ranges from medium to dark brown with occasional reddish-brown mottling in the older unit (Q4). Q4 and Q5 correlate with several units mapped by Barrows and others (1985) as older alluvium and related surficial deposits. They also correlate, in part, with older Quaternary (Qoa) deposits mapped by Dibblee (2002).

Latest Pleistocene to Holocene alluvial fan and wash sediments (Q6) exposed in the northeastern part of the quadrangle are unconsolidated, mainly sandy and silty sediments. Soils on these alluvial fan and colluvial materials are weakly developed. These sediments correlate closely in age with the sediments mapped as various younger alluvium and related surficial deposits by Barrows and others (1985) as well as Qa and Qg of Dibblee (2002).

Quaternary Deposits Exposed Within The San Andreas Rift Zone

As mapped by Barrows and others (1985), the oldest Quaternary alluvial unit exposed within the rift zone on the northern side of the San Andreas Fault is the Harold Formation (Qh). The Harold Formation consists of light brown to buff or dark gray to reddish brown, silty, sandy, and gravelly fluvial, alluvial fan, and playa deposits. It is widespread east of 106th Street East and south of Fort Tejon Road where it characteristically contains a clast assemblage that implies a western source area south of the San Andreas Fault (Barrows, 1987). Near the fault Harold Formation sediments dip steeply to vertically but, with distance, the dips become gentler to nearly horizontal.

Very coarse boulder gravel of Little Rock Creek (Qbl) that rests upon exposures of the Anaverde and Harold formations is common on hills close to the northern side of the San Andreas Fault. Qbl contains well-rounded cobbles and boulders up to 2 m long of distinctive rock types, such as porphyroblastic K-feldspar and hornblende (spotted) varieties of Lowe Granodiorite in a dark red to brown matrix. The composition of the boulder gravel clearly indicates that the deposits have been transported tectonically by right-lateral displacement. Boulder gravel (Qbl) is inferred to be of late Pleistocene age (Barrows, 1980; 1987).

The remaining Quaternary alluvial units north of the San Andreas Fault include patches of older alluvium (Qoa) that are slightly elevated above modern surfaces. Much of the area in the northern part of the quadrangle is covered by modern alluvium (Qal) and, locally, on the slopes of hills of exposed bedrock, slope wash deposits (Qsw). A few modern streams and washes have deposited material (Qsc) across the alluvium.

South of the San Andreas Fault, a variety of Quaternary alluvial deposits rests unconformably upon Tertiary sedimentary and volcanic rocks and pre-Tertiary basement rocks. Here, the Harold Formation is locally deformed, exhibits tilted layers, and is typically finer grained than younger alluvial deposits. The remaining Quaternary older alluvial units mapped by Barrows and others (1985) consist of cap deposits (Qcp) on hilltops and ridges, older alluvial fan (Qof or Qoa; Dibblee, 2002) deposits, and older alluvium (Qoa). Younger (modern) units mapped by Barrows and others (1985) and Dibblee (2002) consist of alluvium (Qal or Qa;), slope wash deposits (Qsw), alluvial fan (Qf), ponded alluvium (Qpa) and stream-channel deposits (Qsc or Qg).

Most of the area between the San Andreas Rift Zone and the southern boundary of the study area is mapped by Dibblee (2002) as older dissected alluvial sand and gravel deposits composed mainly of granitic and gneissic detritus (Qoa). Dibblee (2002) also identifies younger gravelly material deposited along canyon streams (Qg).

Structural Geology

The dominant structural feature within the Juniper Hills Quadrangle is the San Andreas Fault Zone, which crosses the entire quadrangle and separates geologic terranes with dissimilar rock assemblages. Tectonically associated with the main trace and most recently active faults of the San Andreas Fault Zone are several regional faults that lie both north and south of the San Andreas Fault. North of the San Andreas Fault is the Little Rock Fault. On the south, the Northern Nadeau Fault, the Southern Nadeau-Holmes Fault, and the Punchbowl Fault all generally lie subparallel to the main trace. A narrow belt of distinctive Punchbowl Formation rocks lies between the Southern Nadeau-Holmes Fault and the Punchbowl Fault as mapped by Barrows (1980). Part of the Punchbowl Syncline, spectacularly exposed in the Valyermo Quadrangle to the east, occurs in the eastern part of the quadrangle.

Topographically, the San Andreas Fault lies within the San Andreas Rift Zone, which is defined by linear ridges, troughs, and deflected and offset drainage courses. These features have resulted from numerous surface-faulting earthquakes in late Quaternary time. This segment includes traces that ruptured during the great 1857 Fort Tejon earthquake. Active faults within and adjacent to the rift zone have been included in the Official Earthquake Fault Zone prepared by CGS (DOC, 1974). The San Andreas Fault is considered to be a major potential seismic source (Petersen and others, 1996; also see section 3 of this report).

ENGINEERING GEOLOGY

As stated above, soils that are generally susceptible to liquefaction are mainly late Quaternary alluvial and fluvial sedimentary deposits and artificial fill. Deposits that contain saturated, loose sandy and silty soils are most susceptible to liquefaction. Lithologic descriptions and soil test results reported in geotechnical borehole logs provide valuable information regarding subsurface geology, ground-water levels, and the engineering characteristics of sedimentary deposits.

Of particular value in liquefaction evaluations are logs that report the results of standard penetration tests. Standard Penetration Tests (SPTs) provide a uniform measure of the penetration resistance of geologic deposits and are commonly used as an index of soil density. This in-field test consists of counting the number of blows required to drive a split-spoon sampler (1.375-inch inside diameter) one foot into the soil at the bottom of a borehole at chosen intervals while drilling. The driving force is provided by dropping a 140-pound hammer weight 30 inches. The SPT is formally defined and specified by the American Society for Testing and Materials in test method D1586 (ASTM, 1999). Recorded blow counts for penetration tests where the sampler diameter, hammer weight or drop distance differ from those specified for an SPT (ASTM D1586), are converted to SPT-equivalent blow counts. The actual and converted SPT blow counts are normalized to a common reference, effective-overburden pressure of one atmosphere (approximately one ton per square foot) and a hammer efficiency of 60 percent using a method described by Seed and Idriss (1982) and Seed and others (1985). This normalized blow count is referred to as $(N_1)_{60}$.

The Seed-Idriss Simplified Procedure for liquefaction evaluation was developed primarily for clean sand and silty sand. As described above, results depend greatly on accurate evaluation of in-situ soil density as measured by the number of soil penetration blow counts using an SPT sampler. However, many of the Holocene alluvial deposits in the study area contain a significant amount of gravel. In the past, gravelly soils were considered not to be susceptible to liquefaction because the high permeability of these soils presumably would allow the dissipation of pore pressures before liquefaction could occur. However, liquefaction in gravelly soils has been observed during earthquakes, and recent laboratory studies have shown that gravelly soils are susceptible to liquefaction (Ishihara, 1985; Harder and Seed, 1986; Budiman and Mohammadi, 1995; Evans and Zhou, 1995; and Sy and others, 1995). SPT-derived density measurements in gravelly soils are unreliable and generally too high. They are likely to lead to overestimation of the density of the soil and, therefore, result in an underestimation of the liquefaction susceptibility. To identify potentially liquefiable units where the N values appear to have been affected by gravel content, correlations were made with boreholes in the same unit where the N values do not appear to have been affected by gravel content.

During the initial stages of this investigation, CGS obtained logs of geotechnical boreholes that had been drilled in various localities within Antelope Valley and the adjacent foothill region of the San Gabriel Mountains. Staff collected the logs from the files of the cities of Lancaster and Palmdale, California Department of Transportation, Los Angeles County Public Works Department, and Earth Systems, Inc. Several of the logs collected are from boreholes drilled within the Juniper Hills Quadrangle. Additional subsurface information is provided in logs of water wells also drilled in the study area.

Examination of borehole logs and Quaternary geology maps indicate that much of area north of the San Andreas Fault is covered by sedimentary deposits composed of young, loose to moderately dense, sandy and silty sediments. South of the fault, less extensive deposits of young, loose sediments are found in isolated areas and within major stream drainages, including Pallett Creek.

Geologic Map Unit*	Material Type	Consistency	Age	Liquefaction Susceptibility**
stream channel, wash (Q7; Qsc; Qg)	medium to coarse sand and gravel	very loose	latest Holocene	high
sand dune (Qsd)	sand	very loose	Holocene & late Pleistocene	high
alluvium, alluvial fan, (Q6; Qa: Qf, Ql, Qpa, Qt)	sand, gravel, & silt	loose to moderately dense	Holocene & late Pleistocene	high to moderate
alluvium, alluvial fan (Q4, Q5; Qoa, Qof, Qopo)	gravel, sand, silt, clay	dense	late Pleistocene	low
alluvium, alluvial fan (Q1, Q2, Q3; Qsb, Qn, Qs:Qoa)	gravel, sand, silt, clay	dense	late Pleistocene	low
alluvium, alluvial fan, playa Harold Formation	gravel, sand, silt, clay	very dense	Pleistocene	low

* see Table 1.1 for map unit correlations between Ponti and Burke (1980), Barrows and others (1985), and Dibblee (2002).

**when saturated

Table 1.2. Quaternary Map Units Used in the Juniper Hills 7.5-Minute Quadrangle and Their Geotechnical Characteristics and Liquefaction Susceptibility

GROUND WATER

An essential element in evaluating liquefaction susceptibility is the determination of the depths at which soils are saturated by ground water. Saturation reduces the normal effective stress acting on loose, near-surface sandy deposits, thereby increasing the likelihood of liquefaction (Youd, 1973). For zoning purposes, "near surface deposits" include those sediments between 0 and 40 feet deep, the interval being derived from item 4a of the SMGB criteria for delineating seismic hazard zones in California (DOC, 2000; see Criteria for Zoning section of this report). Liquefaction evaluations, therefore, concentrate on areas where investigations indicate that young Quaternary sediments might be saturated within 40 feet of the ground surface. Unfortunately, unpredictable and sometimes dramatic fluctuations in ground water caused by natural processes and human activities make it impossible to anticipate water levels that might exist at the time of future earthquakes. For that reason, CGS uses historically high ground-water levels for evaluating and zoning liquefaction potential. This approach assumes that even in areas where levels are presently significantly lower, ground water could return to historically high levels in the future. This, in fact, has occurred in basins where water importing urbanized areas have replaced vast farm and orchard lands that were characterized by substantial ground-water withdrawal (for example, Simi Valley, Ventura County) as well as in basins where large-scale ground-water recharge programs are employed.

Plate 1.2 depicts historically shallowest depths to ground water in areas of the Juniper Hills Quadrangle covered by Quaternary sediments, which include parts of the Antelope Valley, San Andreas Rift Zone, and stream canyons in the San Gabriel foothills. Historically shallowest ground-water levels throughout much of the quadrangle are generally deeper than 40 feet. Exceptions are: (1) active washes that extend out onto the Antelope Valley floor from the San Gabriel Mountains; (2) alluviated areas within the San Andreas Rift Zone in restricted basins or where subsurface flow is being restricted by ground-water barriers; and (3) restricted stream canyon environments where saturation is assumed to occur during wet seasons.

Sources of ground-water data used in this report include: Johnson (1911); Thompson (1929); California Department of Water Resources (1965); and the California Department of Water Resources (2003).

PART II

LIQUEFACTION POTENTIAL

Liquefaction may occur in water-saturated sediment during earthquakes. Liquefied sediment loses strength and may fail, causing damage to buildings, bridges, and other structures. Many methods for mapping liquefaction hazard have been proposed. Youd (1991) highlights the principal developments and notes some of the widely used criteria. Youd and Perkins (1978) demonstrate the use of geologic criteria as a qualitative characterization of liquefaction susceptibility and introduce the mapping technique of combining a liquefaction susceptibility map and a liquefaction opportunity map to produce a liquefaction potential map. Liquefaction susceptibility depends on the capacity of sediment to resist liquefaction. Liquefaction opportunity depends on the potential seismic ground shaking intensity.

The method applied in this study for evaluating liquefaction potential is similar to that of Tinsley and others (1985). Tinsley and others (1985) applied a combination of the techniques used by Seed and others (1983) and Youd and Perkins (1978) for their mapping of liquefaction hazards in the Los Angeles region. CGS's method combines geotechnical analyses, geologic and hydrologic mapping, and probabilistic earthquake shaking estimates, but follows criteria adopted by the SMGB (DOC, 2000).

LIQUEFACTION SUSCEPTIBILITY

Liquefaction susceptibility reflects the relative resistance of a soil to loss of strength when subjected to ground shaking. Physical properties of soil such as sediment grain-size distribution, compaction, cementation, saturation, and depth govern the degree of resistance to liquefaction. Some of these properties can be correlated to a sediment's geologic age and environment of deposition. With increasing age, relative density may increase through cementation of the particles or compaction caused by the weight of the overlying sediment. Grain-size characteristics of a soil also influence susceptibility to liquefaction. Sand is more susceptible than silt or gravel, although silt of low plasticity is treated as liquefiable in this investigation. Cohesive soils generally are not considered susceptible to liquefaction. Such soils may be vulnerable to strength loss with remolding and represent a hazard that is not addressed in this investigation. Soil characteristics and processes that result in higher measured penetration resistances generally indicate lower liquefaction susceptibility. Thus, blow count and cone penetrometer values are useful indicators of liquefaction susceptibility.

Saturation is required for liquefaction, and the liquefaction susceptibility of a soil varies with the depth to ground water. Very shallow ground water increases the susceptibility to liquefaction (soil is more likely to liquefy). Soils that lack resistance (susceptible soils) typically are saturated, loose and sandy. Soils resistant to liquefaction include all soil types that are dry, cohesive, or sufficiently dense.

CGS's map inventory of areas containing soils susceptible to liquefaction begins with evaluation of geologic maps and historical occurrences, cross-sections, geotechnical test data, geomorphology, and ground-water hydrology. Soil properties and soil conditions such as type, age, texture, color, and consistency, along with historical depths to ground water are used to identify, characterize, and correlate susceptible soils. Because Quaternary geologic mapping is based on similar soil observations, liquefaction susceptibility maps typically are similar to Quaternary geologic maps

LIQUEFACTION OPPORTUNITY

Liquefaction opportunity is a measure, expressed in probabilistic terms, of the potential for strong ground shaking. Analyses of in-situ liquefaction resistance require assessment of liquefaction opportunity. The minimum level of seismic excitation to be used for such purposes is the level of peak ground acceleration (PGA) with a 10 percent probability of exceedance over a 50-year period (DOC, 2000). The earthquake magnitude used in CGS's analysis is the magnitude that contributes most to the calculated PGA for an area.

For the Juniper Hills Quadrangle, PGAs ranging from 0.55 to 0.75g, resulting from a predominant earthquake of magnitude 7.8, were used for liquefaction analyses. The PGA and magnitude values were based on de-aggregation of the probabilistic hazard at the 10 percent in 50-year hazard level (Petersen and others, 1996; Cramer and Petersen, 1996). See the ground motion portion (Section 3) of this report for further details.

Quantitative Liquefaction Analysis

CGS performs quantitative analysis of geotechnical data collected by staff to evaluate liquefaction potential using the Seed-Idriss Simplified Procedure (Seed and Idriss, 1971; Seed and others, 1983; National Research Council, 1985; Seed and others, 1985; Seed and Harder, 1990; Youd and Idriss, 1997; Youd and others, 2001). Unfortunately, only four logs of geotechnical boreholes drilled within the Juniper Hills Quadrangle were found (Plate 1.2) during the this study and none of these included blow-count data from down-hole penetration tests. Consequently, no liquefaction analysis was performed for this study.

When data are available, CGS employs the Seed-Idriss Simplified Procedure to calculate soil resistance to liquefaction, expressed in terms of cyclic resistance ratio (CRR), based on SPT results, ground-water level, soil density, moisture content, soil type, and sample depth. CRR values are then compared to calculated earthquake-generated shear stresses expressed in terms of cyclic stress ratio (CSR). The Seed-Idriss Simplified Procedure requires normalizing earthquake loading relative to a M7.5 event for the liquefaction analysis. To accomplish this, CGS's analysis uses the Idriss magnitude-scaling factor (MSF) (Youd and Idriss, 1997). It is convenient to think in terms of a factor of safety (FS) relative to liquefaction, where: FS = (CRR / CSR) * MSF. FS, therefore, is a quantitative measure of liquefaction potential. CGS uses a factor of safety of 1.0 or less, where CSR equals or exceeds CRR, to indicate the presence of potentially liquefiable soil. While an FS of 1.0 is considered the "trigger" for liquefaction, for a site-specific analysis an FS of as much as 1.5 may be appropriate depending on the vulnerability of the site and related structures.

The CGS liquefaction analysis program calculates an FS for each geotechnical sample where blow counts were recorded. Typically, multiple tests are performed at prescribed intervals in each borehole. The program then independently calculates an FS for each non-clay layer that includes at least one penetration test using the minimum $(N_1)_{60}$ value for that layer. The minimum FS value of the layers penetrated within the upper 40 feet of the borehole is used to determine the liquefaction potential for each borehole location. The reliability of FS values varies according to the quality of the geotechnical data. FS, as well as other considerations such as slope, presence of free faces, and thickness and depth of potentially liquefiable soil, are evaluated in order to construct liquefaction potential maps, which are then used to make a map showing zones of required investigation.

LIQUEFACTION ZONES

Criteria for Zoning

Areas underlain by materials susceptible to liquefaction during an earthquake were included in liquefaction zones using criteria developed by the Seismic Hazards Mapping Act Advisory Committee and adopted by the SMGB (DOC, 2000). Under those guideline criteria, liquefaction zones are areas meeting one or more of the following:

1. Areas known to have experienced liquefaction during historical earthquakes
2. All areas of uncompacted artificial fill containing liquefaction-susceptible material that are saturated, nearly saturated, or may be expected to become saturated
3. Areas where sufficient existing geotechnical data and analyses indicate that the soils are potentially liquefiable
4. Areas where existing geotechnical data are insufficient

In areas of limited or no geotechnical data, susceptibility zones may be identified by geologic criteria as follows:

a) Areas containing soil deposits of late Holocene age (current river channels and their historic floodplains, marshes and estuaries), where the M7.5-weighted peak acceleration that has a 10 percent probability of being exceeded in 50 years is greater than or equal to 0.10 g and the water table is less than 40 feet below the ground surface; or

b) Areas containing soil deposits of Holocene age (less than 11,000 years), where the M7.5-weighted peak acceleration that has a 10 percent probability of being exceeded in 50 years is greater than or equal to 0.20 g and the historical high water table is less than or equal to 30 feet below the ground surface; or

c) Areas containing soil deposits of latest Pleistocene age (11,000 to 15,000 years), where the M7.5-weighted peak acceleration that has a 10 percent probability of being exceeded in 50 years is greater than or equal to 0.30 g and the historical high water table is less than or equal to 20 feet below the ground surface.

Application of SMGB criteria to liquefaction zoning in the Juniper Hills Quadrangle is summarized below.

Areas of Past Liquefaction

Evidence of prehistoric liquefaction in the sediments along Pallett Creek near the eastern boundary of the quadrangle has been intensively documented by Sieh (1978; 1984) in trenches dug along the trace of the San Andreas Fault. A variety of features, inferred to have been generated by liquefaction during large earthquakes, such as "sandblows" are described.

Artificial Fills

Artificial fill in the Juniper Hills Quadrangle large enough to show at the scale of mapping is limited to construction along the California Aqueduct. Since these fills are known to be engineered, liquefaction potential in such areas depends on soil conditions in underlying strata. Non-engineered fills are commonly loose and uncompacted and, therefore, likely to liquefy during strong earthquake shaking.

Areas with Sufficient Existing Geotechnical Data

CGS staff did not find sufficient existing geotechnical data within any area of the Juniper Hills Quadrangle. Only four logs of geotechnical boreholes drilled in the quadrangle were located during the data-gathering phase of the study. Although they provide important information on the lithology, density, and moisture content of sedimentary deposits, no penetration tests were reported in any of the logs. Therefore, no liquefacton analyses were performed.

Areas with Insufficient Existing Geotechnical Data

Although geotechnical data available within the study area are insufficient for evaluating Quaternary deposits for liquefaction, logged lithology in boreholes and water wells, and data from drilling in similar geologic environments in adjacent quadrangles, indicate that young Quaternary deposits in Antelope Valley, the San Andreas Rift Zone, and stream canyons of the San Gabriel Mountains contain loose, sandy material. Such deposits could liquefy where saturated within 40 feet of the surface under historically shallowest ground-water conditions presented on Plate 1.2. Therefore, these areas are designated "zones of required investigation" on the Seismic Hazard Zone Map of the Juniper Hills Quadrangle.

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SECTION 2
EARTHQUAKE-INDUCED LANDSLIDE EVALUATION REPORT

Earthquake-Induced Landslide Zones in the Juniper Hills 7.5-Minute Quadrangle, Los Angeles County, California

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PURPOSE

The Seismic Hazards Mapping Act (the Act) of 1990 (Public Resources Code, Chapter 7.8, Division 2) directs the California Department of Conservation (DOC), Division of Mines and Geology (DMG) [now called California Geological Survey (CGS)] to delineate Seismic Hazard Zones. The purpose of the Act is to reduce the threat to public health and safety and to minimize the loss of life and property by identifying and mitigating seismic hazards. Cities, counties, and state agencies are directed to use seismic hazard zone maps prepared by CGS in their land-use planning and permitting processes. The Act requires that site-specific geotechnical investigations be performed prior to permitting most urban development projects within the hazard zones. Evaluation and mitigation of seismic hazards are to be conducted under guidelines established by the California State Mining and Geology Board (DOC, 1997). The text of this report is on the Internet at http://gmw.consrv.ca.gov/shmp/SHMPsp117.asp

Following the release of DMG Special Publication 117 (DOC, 1997), agencies in the Los Angeles metropolitan region sought more definitive guidance in the review of geotechnical investigations addressing landslide hazards. The agencies made their request through the Geotechnical Engineering Group of the Los Angeles Section of the American Society of Civil Engineers (ASCE). This group convened an implementation committee in 1998 under the auspices of the Southern California Earthquake Center (SCEC). The committee, which consisted of practicing geotechnical engineers and engineering geologists, released an overview of the practice of landslide analysis, evaluation, and mitigation techniques (SCEC, 2002). This text is also on the Internet at: http://www.scec.org/

This section of the evaluation report summarizes seismic hazard zone mapping for earthquake-induced landslides in the Juniper Hills 7.5-Minute Quadrangle. Section 1 (addressing liquefaction) and Section 3 (addressing earthquake shaking) complete the report, which is one of a series that summarizes the preparation of seismic hazard zone maps within the state (Smith, 1996). Additional information on seismic hazard zone mapping in California can be accessed on the California Geological Survey's Internet page: http://www.consrv.ca.gov/CGS/index.htm

BACKGROUND

Landslides triggered by earthquakes historically have been a significant cause of earthquake damage. In California, large earthquakes such as the 1971 San Fernando, 1989 Loma Prieta, and 1994 Northridge earthquakes triggered landslides that were responsible for destroying or damaging numerous structures, blocking major transportation corridors, and damaging life-line infrastructure. Areas that are most susceptible to earthquake-induced landslides are steep slopes in poorly cemented or highly fractured rocks, areas underlain by loose, weak soils, and areas on or adjacent to existing landslide deposits. These geologic and terrain conditions exist in many parts of California, including numerous hillside areas that have already been developed or are likely to be developed in the future. The opportunity for strong earthquake ground shaking is high in many parts of California because of the presence of numerous active faults. The combination of these factors constitutes a significant seismic hazard throughout much of California, including the hillside areas of the Juniper Hills Quadrangle.

METHODS SUMMARY

The mapping of earthquake-induced landslide hazard zones presented in this report is based on the best available terrain, geologic, geotechnical, and seismological data. If unavailable or significantly outdated, new forms of these data were compiled or generated specifically for this project. The following were collected or generated for this evaluation:

- Digital terrain data were used to provide an up-to-date representation of slope gradient and slope aspect in the study area.
- Geologic mapping was used to provide an accurate representation of the spatial distribution of geologic materials in the study area. In addition, a map of existing

landslides, whether triggered by earthquakes or not, was prepared.

- Geotechnical laboratory test data were collected and statistically analyzed to quantitatively characterize the strength properties and dynamic slope stability of geologic materials in the study area.
- Seismological data in the form of CGS probabilistic shaking maps and catalogs of strong-motion records were used to characterize future earthquake shaking within the mapped area.

The data collected for this evaluation were processed into a series of GIS layers using commercially available software. A slope stability analysis was performed using the Newmark method of analysis (Newmark, 1965), resulting in a map of landslide hazard potential. The earthquake-induced landslide hazard zone was derived from the landslide hazard potential map according to criteria developed in a CGS pilot study (McCrink and Real, 1996; McCrink, 2001) and adopted by the State Mining and Geology Board (DOC, 2000).

SCOPE AND LIMITATIONS

The methodology used to make this map is based on earthquake ground-shaking estimates, geologic material-strength characteristics and slope gradient. These data are gathered from a variety of outside sources. Although the selection of data used in this evaluation was rigorous, the quality of the data is variable. The State of California and the Department of Conservation make no representations or warranties regarding the accuracy of the data gathered from outside sources.

Earthquake-induced landslide zone maps are intended to prompt more detailed, site-specific geotechnical investigations as required by the Act. As such, these zone maps identify areas where the potential for earthquake-induced landslides is relatively high. Due to limitations in methodology, it should be noted that these zone maps do not necessarily capture all potential earthquake-induced landslide hazards. Earthquake-induced ground failures that are not addressed by this map include those associated with ridge-top spreading and shattered ridges. It should also be noted that no attempt has been made to map potential run-out areas of triggered landslides. It is possible that such run-out areas may extend beyond the zone boundaries. The potential for ground failure resulting from liquefaction-induced lateral spreading of alluvial materials, considered by some to be a form of landsliding, is not specifically addressed by the earthquake-induced landslide zone or this report. See Section 1, Liquefaction Evaluation Report for the Juniper Hills Quadrangle, for more information on the delineation of liquefaction zones.

The remainder of this report describes in more detail the mapping data and processes used to prepare the earthquake-induced landslide zone map for the Juniper Hills Quadrangle. The information is presented in two parts. Part I covers physiographic, geologic and engineering geologic conditions in the study area. Part II covers the preparation of landslide hazard potential and landslide zone maps.

PART I

PHYSIOGRAPHY

Study Area Location and Physiography

The Juniper Hills Quadrangle covers about 62 square miles in northeastern Los Angeles County along the boundary between the San Gabriel Mountains and the Mojave Desert. The center of the area is 15 miles southeast of Palmdale and 32 miles northeast of the Los Angeles Civic Center. The entire quadrangle consists of unincorporated Los Angeles County land. The San Gabriel Mountains rise abruptly on the south above broad alluvial fans and low hills that underlie the rural community of Juniper Hills, which consists of scattered rural residences and small ranches. Out on the Mojave Desert, part of the community of Pearblossom is located within the northeastern corner of the quadrangle. The boundary of the Angeles National Forest cuts across the quadrangle in a stair-step fashion from the northwestern corner to the center of the eastern boundary. National forest land covers about half of the quadrangle. Only about 50 percent (31 square miles) of the quadrangle was evaluated for zoning.

The primary geologic element within the quadrangle is the northwest-striking San Andreas Fault Zone. It is manifest as a series of linear hills and trough-like valleys that define the topography within the San Andreas Rift. Several canyons dissect the steep mountain front and cross the sloping terrain under Juniper Hills. The northward-sloping alluvial fan and scattered hills are typically brushy, arid desert land. In the part of the quadrangle subject to development the steepest slopes are generally along the margins of the incised creek canyons. The highest elevation in the quadrangle is along the crest of Pleasant View Ridge at 7,983 feet. The lowest elevation, below 3,200 feet, occurs along the northern edge of the area.

Access to the region is via Pearblossom Highway (State Highway 138), which is just north of the quadrangle. Fort Tejon Road and other county roads, especially 106th Street East and 131st Street East also provide access. A segment of the California Aqueduct crosses the northeastern corner of the area.

Digital Terrain Data

The calculation of slope gradient is an essential part of the evaluation of slope stability under earthquake conditions. An accurate slope gradient calculation begins with an up-to-date map representation of the earth's surface in the form of a digital topographic map. Within the Juniper Hills Quadrangle, a Level 2 digital elevation model (DEM) was obtained from the USGS (U.S. Geological Survey, 1993). This DEM, prepared from the 7.5-minute quadrangle topographic contours based on 1957 aerial photography, has a 10-meter horizontal resolution and a 7.5-meter vertical accuracy.

A slope map was made from the DEM using a third-order, finite difference, center-weighted algorithm (Horn, 1981). The manner in which the slope map was used to prepare the zone map will be described in subsequent sections of this report.

GEOLOGY

Bedrock and Surficial Geology

The geologic map used as background geology for the Juniper Hills Quadrangle was prepared from three sources. Detailed geologic maps of the San Andreas Fault Zone, including the segment that traverses the Juniper Hills Quadrangle, were prepared by Barrows and others (1985, Plates 1F and 1G). This is the primary source of the data in the background geologic map. Ponti and Burke (1980) mapped the Quaternary geology of eastern Antelope Valley and vicinity, including the northern part of the Juniper Hills Quadrangle. The pre-Quaternary rocks are generalized on the Ponti and Burke (1980) map, which was used to fill in the northeastern corner of the complied geologic map. Geologic maps from both of the above-mentioned sources were digitized by the Southern California Areal Mapping Project [SCAMP]. Part of a geologic map by Dibblee (2002) was digitized by CGS to fill in the portion of the Juniper Hills Quadrangle south of the detailed strip map along the fault zone. During the search for landslides in the field, observations were made of exposures, aspects of weathering, and general surface expression of the geologic units.

Barrows (1987) discussed the geology of the Juniper Hills area in detail. Because of the contrast in the geologic framework and rock assemblages on opposite sides of the San Andreas Fault, it is logical to separate the description of the units in this region into two sections.

Geologic units north of the San Andreas Fault

North of the San Andreas Fault a batholith of medium- to coarse-grained buff-weathering quartz monzonite to gneissic granodiorite that comprises Holcomb Quartz Monzonite (hqm) is widely exposed in the uplifted terrain near the fault and in buttes within Antelope Valley. The crystalline rocks contain, locally, inclusions of metasedimentary rocks (ms), including biotite schist and amphibolite, and gray to white graphitic marble (m) in the northeastern corner of the quadrangle. Close to the San Andreas Fault are slivers of crushed leucocratic granitic rocks (grc), especially near Pallet Creek. In the northeastern portion of the quadrangle compiled from Ponti and Burke (1980) the quartz monzonite is labeled gr-m.

The predominant Tertiary unit north of the San Andreas Fault is the Anaverde Formation of upper Miocene (?) and/or lower Pliocene age. Several steeply dipping to vertical members of the Anaverde Formation are exposed adjacent to the San Andreas Fault in the northwestern corner of the quadrangle. Anaverde Formation consists primarily of coarse, massive to poorly bedded, arkosic sandstone and interbedded shale. The sandstone members are subdivided on the basis of color: white (Taw), red (Tar), and buff (Tab).

Interlayered with the sandstone is thin-bedded, dark gray to brown, gypsiferous clay shale (Tac).

A few exposures of sheared and crushed pebbly sandstone of the Juniper Hills Formation (TQjh) occur in fault slivers on the northern side of the San Andreas Fault, especially in the vicinity of Pallet Creek Road.

The oldest Quaternary alluvial unit on the northern side of the San Andreas Fault is the Harold Formation (Qh). Harold Formation consists of light brown to buff or dark gray to reddish brown, silty, sandy, and gravelly fluvial, alluvial fan, and playa deposits. It is widespread east of 106th Street East and south of Fort Tejon Road where it characteristically contains a clast assemblage that implies a source area to the west and from the south of the San Andreas Fault (Barrows, 1987). Near the fault Harold Formation sediments dip steeply to vertically, but with distance, the dips become gentler to nearly horizontal.

Very coarse boulder gravel of Little Rock Creek (Qbl) that rests upon Anaverde Formation and Harold Formation is common on hills close to the northern side of the San Andreas Fault. Qbl contains well-rounded cobbles and boulders up to 2 m long of distinctive rock types, such as porphyroblastic K-feldspar and hornblende (spotted) varieties of Lowe Granodiorite in a dark red to brown matrix. The composition of the boulder gravel clearly indicates that the deposits have been transported tectonically by right-lateral displacement. Boulder gravel (Qbl) is inferred to be of late Pleistocene age (Barrows, 1980; 1987). About one-half mile west of 106th Street East are exposures of a distinctive variety of the boulder gravel of Little Rock Creek, called Qblm, that consists entirely of blocks up to 45 cm of coarsely crystalline marble.

The remaining Quaternary alluvial units include patches of older alluvium (Qoa) that are slightly elevated above modern surfaces. Much of the area in the northern part of the quadrangle is covered by modern alluvium (Qal) and, locally, on the slopes of hills of exposed bedrock slope wash deposits (Qsw). A few stream channel deposits (Qsc) interrupt the alluvium. The alluvium is part of the vast apron that extends out into the Antelope Valley. Units in the northeastern portion if the geologic map compiled from Ponti and Burke (1980) include a variety of late Quaternary alluvial units including Q1-3c, Q4-5c, Q6c, Q7c and Q7vc. The earliest unit has the lowest number and c means coarse and vc means very coarse sediments.

Geologic units south of the San Andreas Fault

A complex pre-Cenozoic history of intrusion and metamorphism has resulted in a large variety of basement rock types in the Juniper Hills Quadrangle. Furthermore, disruption of the basement complex rocks by episodes of large-displacement, especially lateral, faulting has added to the complexity of the regional geologic setting (Barrows, 1980; 1987). In the Juniper Hills Quadrangle south of the San Andreas Fault several through-going faults that parallel the main San Andreas Fault dominate the geologic structure. The southernmost of these regional boundary faults is the Punchbowl Fault. The San Gabriel Mountains rise abruptly from a broad apron of older alluvial fan deposits south of the Punchbowl Fault (Dibblee, 2002). In the mountains are dioritic gneisses (gn of Dibblee, 2002; dgn of Barrows, 1980; 1987) that predominantly consist of dark gray to black, hornblende and/or biotite, massive to highly migmatitic gneiss intruded by abundant aplitic dikes. The dioritic gneiss (gn) is inferred to be Precambrian because it is intruded by Triassic Lowe Granodiorite (lgd). In the southeastern corner of the map area aplitic quartz monzonite (gr) is widespread along the mountain front. This unit is typically bright white aplitic granite to medium-grained quartz monzonite. Rocks of the gr unit, mapped as aqm by Barrows (1980) which may be of Cretaceous age (Barrows, 1987), are locally shattered and crushed to a microbreccia. In the Holmes Creek drainage near the eastern boundary of the quadrangle a distinctive topography of cliffs and caves has developed on weathered gr (aqm of Barrows, 1980; 1987). On the western side of the quadrangle bedrock consists of Triassic medium- to coarse-grained porphyritic Lowe Granodiorite (lgd) and associated hornblende diorite gabbro (hdg). Resting upon the Lowe Granodiorite and hornblende diorite gabbro are resistant, reddish-brown-weathering, dark-gray aphanitic to slightly porphyritic lava flows and thick coarse andesite breccias that comprise Vasquez Formation volcanic rocks (Tvv) of Oligocene age. A small patch of white, tuffaceous volcaniclastic sandstone (Tvts) occurs beneath Vasquez Formation lava in the northwestern part of the quadrangle (Barrows and others, 1985).

Dibblee (2002) inferred that the Punchbowl Fault is located near the base of the mountains, and mapped the deposits exposed in ravines within the alluvial fan of Juniper Hills as three subunits of the Punchbowl Formation. These three subunits are conglomerate of volcanic detritus (Tpcg), red conglomerate that includes schist debris (Tprc), and light-colored arkosic sandstone (Tps). He also mapped a small patch adjacent to 106th Street East as Vasquez Formation volcanic rocks (Tva).

A contrasting interpretation of the location of the Punchbowl Fault and the nature of the deposits in the area west of 106th Street East is found in the work of Barrows (1980; 1987). Barrows interpreted the location of the Punchbowl Fault to be away from the mountain front and beneath the Juniper Hills fan. Instead of Punchbowl Formation and Vasquez Formation rocks as mapped by Dibblee (2002), Barrows (1980) mapped several distinctive members of the Juniper Hills Formation that are exposed in ravines eroded into the older alluvial fan deposits (Qof) or, farther west, rest upon the basement rocks. The members include: conglomeratic sandstone (TQjhcs), arkosic sandstone (TQjha), volcanic clast conglomerate (TQjhv) containing Vasquez Formation volcanic rocks, red playa deposits (TQjhp), and siltstone (TQjhs). These members are primarily arkosic conglomerate, sandstone, and siltstone. The various members are mapped on the basis of their contained clasts, which were derived from contrasting source terrains. Barrows (1987) concluded that Punchbowl Formation rocks are not present south of the Punchbowl Fault but only occur between the Punchbowl and Southern Nadeau faults.

North of the Punchbowl Fault is a belt of rocks that lies between the Punchbowl Fault and strands of the Southern Nadeau-Holmes Fault, which crosses the entire quadrangle. The oldest rocks in this belt consist of dark gray to black, foliated and complexly deformed hornblende metadiorite and migmatite (dgm). The dioritic gneiss, hornblendite, and migmatite unit is exposed in faulted blocks west of 131st Street East near the Holmes Fault. An intrusion of light-colored coarse-grained granitic rocks (gr and/or gru) is associated with the dgm unit in this area (Barrows, 1980).

The oldest Tertiary sedimentary rocks within the belt between the Punchbowl and Southern Nadeau-Holmes Fault include, near the eastern quadrangle boundary, yellowish-brown to rusty-brown weathering, medium- to coarse-grained, resistant, massive to thick-bedded, pebbly to cobbly, Paleocene marine, gritty sandstone with interbeds of shale that comprise undifferentiated San Francisquito Formation (Tsf). Subunits within the San Francisco Formation include a conglomerate facies (Tsfc), with very resistant, well-rounded boulders and cobbles, and light brown to gray fossiliferous limestone lenses (Tsfl).

Unconformably resting upon San Francisquito Formation near the eastern quadrangle boundary is the arkosic, pebbly to cobbly, white to pinkish diorite-clast member of the non-marine upper Miocene to lower Pliocene Punchbowl Formation (Tp). Punchbowl Formation (Tp) contains granitic, dioritic gneiss, and San Francisquito Formation sandstone clasts and cobbles recycled from San Francisquito Formation conglomerate. Punchbowl Formation rocks are well cemented, as evidenced by the steep to vertical cliffs that occur to the east in the Valyermo Quadrangle. A change in source for the contained clasts occurred during deposition of the Punchbowl Formation that resulted in the deposition of the volcanic-clast member (Tpv) upon the diorite-clast member (Barrows, 1980). Tpv consists of well-indurated, well-stratified coarse pebbly arkosic sandstone with interlayered silty beds and a variety of volcanic clasts of unknown source (not Vasquez Formation) in addition to clasts similar to those in Tp. Dibblee (2002) mapped the Punchbowl Formation rocks near the eastern boundary (equivalent to Tpv of Barrows and others, 1985) as arkosic sandstone (Tps). The volcanic-clast member (Tpv) is the only part of the Punchbowl Formation that is found in the typically highly sheared sliver of rocks between the Punchbowl Fault and the Southern Nadeau-Holmes Fault from just west of 131st Street East to the vicinity of Pearblossom Highway in the Palmdale area (Barrows and others, 1985). No Juniper Hills Formation rocks are found between these two faults.

Within the Juniper Hills Quadrangle most of the bedrock exposed between the Southern Nadeau-Holmes and Northern Nadeau faults is gray to greenish-black, medium-grained hornblende quartz diorite (qd). Large bodies of quartz diorite (qd), locally containing intrusions of leucocratic granitic rocks (gru), pegmatite, and aplite, are bound by inward-dipping thrust faults near Holmes Creek and west of 106th Street East. The faulted contact rocks are red-stained shear zones in the quartz diorite. Small bodies of black, mafic to ultramafic dioritic gneiss and migmatite (dgm) are associated with (intruded by) quartz diorite between 131st Street East and 106th Street East. A distinctive member of the Juniper Hills Formation was mapped by Barrows (1980) in the Juniper Bowl Syncline on both sides of 106th Street East, in the vicinity of Juniper Bowl. This unit, the fine-grained deposit member (TQjhf), consists of light brown to buff, silty sandstone that is a shallow lake or playa deposit with abundant maroon concretions and, locally abundant, Pelona Schist pebbles. Undifferentiated Juniper Hills Formation (TQjh) arkosic sandstone is also present west of 106th Street East. In the same vicinity is a small exposure of the sedimentary breccia member (TQjhsb), which consists of coarse to very coarse angular rubble comprised exclusively of blocks up to one meter in diameter of dioritic gneiss and gneissic hornblende quartz diorite.

Between the Northern Nadeau Fault and the San Andreas Fault, not far from either side of 106th Street East, are small bodies, typically bordered by faults, of crushed gneissic dark greenish-gray quartz diorite and diorite (qd) and dark gray to black extremely contorted migmatitic gneiss (dgm). Well exposed both east and west of 106th Street East, as well, are coarse arkosic sandstone and conglomeratic sandstone units of the undifferentiated Juniper Hills Formation (TQjh). In addition, in the northwestern corner of the quadrangle are several distinctive members of the Juniper Hills Formation. The subunits include an arkosic basal breccia member (TQjhb) that consists of white, coarse, angular, poorly sorted sedimentary breccia and fanglomerate with a variety of granitic and dioritic fragments. The clay shale member (TQjhc), the siltstone member (TQjhs), the mixed clast sandstone member (TQjhm) and the arkosic red sandstone member (TQjhr) are also exposed in the tightly deformed sequence between 2,000 to 4,000 feet south of the San Andreas Fault in the northwestern corner of the Juniper Hills Quadrangle. The clay shale member (TQjhc) is a light brown to nearly black, gypsiferous clay shale with very thin flaggy red sandstone layers. A soft brown expansive clayey soil with abundant glassy-appearing gypsum chips and sparse vegetation typically covers the clay shale member (TQjhc).

A variety of Quaternary alluvial deposits rests unconformably upon Tertiary sedimentary and volcanic rocks and pre-Tertiary basement rocks in the northern half of the Juniper Hills Quadrangle. The oldest of these is the Harold Formation (Qh) of Pleistocene age. Harold Formation consists of weakly to moderately consolidated, massive to moderately well-stratified, light brown, buff, light to dark gray, and reddish brown, silty, sandy, gravelly fluvial, alluvial fan and playa deposits. South of the San Andreas Fault Harold Formation is locally deformed, exhibits tilted layers, and is typically finer grained than younger alluvial deposits.

The remaining Quaternary older alluvial units mapped by Barrows and others (1985) consist of cap deposits (Qcp) on hilltops and ridges, older alluvial fan (Qof or Qoa [Dibblee, 2002]) deposits, and older alluvium (Qoa). Younger (modern) deposits consist of alluvium (Qal or Qa [Dibblee, 2002]), slope wash deposits (Qsw), alluvial fan (Qf), ponded alluvium (Qpa) and stream-channel deposits (Qsc or Qg [Dibblee, 2002]).

Structural Geology

The dominant structural feature within the Juniper Hills Quadrangle is the San Andreas Fault Zone that crosses the entire quadrangle and separates geologic terranes with dissimilar rock assemblages. Tectonically associated with the main trace and most recently active faults of the San Andreas Fault Zone are several regional faults that lie both north and south of the San Andreas Fault. North of the San Andreas Fault is the Little Rock Fault. On the south, the Northern Nadeau Fault, the Southern Nadeau-Holmes Fault, and the Punchbowl Fault all generally lie subparallel to the main trace. A narrow belt of distinctive Punchbowl Formation rocks lies between the Southern Nadeau-Holmes Fault and the Punchbowl Fault as mapped by Barrows (1980). Part of the Punchbowl Syncline, dramatically exposed in the Valyermo Quadrangle to the east, occurs in the eastern part of the quadrangle. Topographically, the San Andreas Fault lies generally within the San Andreas Rift Zone, which is defined by linear ridges, troughs, and deflected and offset drainage courses. These features have resulted from numerous surface-faulting earthquakes in late Quaternary time. South of the broad alluvial fan upon which is located the community of Juniper Hills the San Gabriel Mountains rise abruptly toward Pleasant View Ridge and adjacent rugged terrain that is mostly within the Angeles National Forest and outside of the area evaluated for zoning in the current study.

Landslide Inventory

As a part of the geologic data compilation, an inventory of existing landslides in the Juniper Hills Quadrangle was prepared by field reconnaissance, analysis of stereo-paired aerial photographs and a review of previously published landslide mapping. Landslides were mapped at a scale of 1:24,000. For each landslide included on the map a number of characteristics (attributes) were compiled. These characteristics include the confidence of interpretation (definite, probable and questionable) and other properties, such as activity, thickness, and associated geologic unit(s). Landslides rated as definite and probable were carried into the landslide zoning as described later in this report. Landslides rated as questionable were not carried into the slope stability analysis due to the uncertainty of their existence. The completed landslide map was scanned, digitized, and the attributes were compiled in a database. A version of this landslide inventory is included with Plate 2.1.

Very few landslides were mapped in the Juniper Hills Quadrangle. A rock slide occurs between Matay and Miller Canyons that is probably anthropogenic in origin. Here, the moderately steep slope, underlain by granodiorite (lgdb), may have been rendered unstable by the construction of dirt roads. Smaller rock slides and debris slides also occur in the quartz diorite and Juniper Hills Formation.

Because it is not within the scope of the Act to review and monitor grading practices to ensure past slope failures have been properly mitigated, all documented slope failures, whether or not surface expression currently exists, are included in the landslide inventory.

ENGINEERING GEOLOGY

Geologic Material Strength

To evaluate the stability of geologic materials under earthquake conditions, the geologic map units described above were ranked and grouped on the basis of their shear strength. Generally, the primary source for shear-strength measurements is geotechnical reports prepared by consultants on file with local government permitting departments. Thirty-four shear tests were found for the Juniper Hills Quadrangle, collected from the Los

Angeles County Public Works Department. In addition, shear tests from the Ritter Ridge, Palmdale, Littlerock, and Valyermo quadrangles were used to characterize units with no test data and augment units with minimal data. Quaternary units were found to be consistently medium- to very coarse-grained and, where tested were found to have very similar shear strength characteristics. For these reasons all Quaternary alluvial deposits in the Juniper Hills Quadrangle were combined and treated as one geological unit. Although Dibblee (2002) designated Anaverde Formation sandstone as Tas on his map, the composite geologic map used for the current zoning study did not include Tas as a separate unit. However, this unit is considered texturally equivalent to the Tar and Tab subunits of the Anaverde Formation that do appear on the geologic compilation used for the current study. Accordingly, shear tests collected from the Tas unit in the Ritter Ridge Quadrangle were used to characterize rock strength of the Anaverde Formation.

Average (mean or median) phi values for each strength group are summarized in Table 2.1. For the geologic strength groups (Table 2.2) in the map area, a single shear strength value was assigned and used in our slope stability analysis. A geologic material strength map was made based on the groupings presented in Table 2.1 and Table 2.2, and this map provides a spatial representation of material strength for use in the slope stability analysis.

Existing Landslides

As will be discussed later in this report, the criteria for landslide zone mapping state that all existing landslides that are mapped as definite or probable are automatically included in the landslide zone of required investigation. Therefore, an evaluation of shear strength parameters for existing landslides is not necessary for the preparation of the zone map. However, in the interest of completeness for the material strength map, to provide relevant material strength information to project plan reviewers, and to allow for future revisions of our zone mapping procedures, we have collected and compiled shear strength data considered representative of existing landslides within the quadrangle.

The strength characteristics of existing landslides (Qls) must be based on tests of the materials along the landslide slip surface. Ideally, shear tests of slip surfaces formed in each mapped geologic unit would be used. However, this amount of information is rarely available, and for the preparation of the earthquake-induced landslide zone map it has been assumed that all landslides within the quadrangle have the same slip surface strength parameters. We collect and use primarily “residual” strength parameters from laboratory tests of slip surface materials tested in direct shear or ring shear test equipment. Back-calculated strength parameters, if the calculations appear to have been performed appropriately, have also been used. For the Juniper Hills Quadrangle, no shear tests of landslide slip surface materials were available. A phi value of 16 degrees was derived from shear tests collected in the Mint Canyon Quadrangle to the west and was judged to be representative of the relatively few landslides in the study area.

JUNIPER HILLS QUADRANGLE SHEAR STRENGTH GROUPS							
	Formation Name	**Number Tests**	**Mean/Median Phi (deg)**	**Mean/Median Group Phi (deg)**	**Mean/Median Group C (psf)**	**No Data: Similar Lithology**	**Phi Values Used in Stability Analyses**
GROUP 1	**gr**	**41**	**34/35**	**35**	**361/239**	**dgm, gn**	**35**
	hqm	**11**	**36**			**grc, grd**	
	lgd	**6**	**38/37**			**gr-m, gru**	
	qd	**1**	**38**			**hd, hdg**	
						lgdb, m	
						ms	
GROUP 2	**Q***	**66**	**30/31**	**30/31**	**216/140**	**af, Q****	**30**
	Tar	**2**	**29**			**Tab, Taw**	
	Tas	**18**	**30/31**			**Tp, Tpb,**	
	Tvv	**3**	**34/31**			**Tpcg, Tprc,**	
						Tps, Tpv	
						TQjh, TQjha	
						TQjhb	
						TQjhcs	
						TQjhf, TQjhm,	
						TQjhp, TQjhr	
						TQjhs	
						TQjhsb	
						TQjhv	
						Tsf, Tsfc,	
						Tsfl	
						Tva, Tvts	
						Tvts, Tvv	
GROUP 3	**Tac**	**9**	**24/26**	**24/26**	**477/280**	**TQjhc**	**26**
GROUP 4	**Qls**						**16**

Q* = Q4-5c, Qa, Qf, Qoa, Qof, Qovs, Qsc, Qsw

Q = Q1-3c, Q6c, Q7c, Q7vc, Qal, Qbl, Qblm, Qcp, Qg, Qh, Qoc, Qos, Qpa**

Formations name abbreviations from Dibblee (2002), Ponti and Burke (1980) and Barrows and others (1985)

Table 2.1. Summary of the Shear Strength Statistics for the Juniper Hills Quadrangle.

SHEAR STRENGTH GROUPS FOR THE JUNIPER HILLS 7.5-MINUTE QUADRANGLE			
GROUP 1	**GROUP 2**	**GROUP 3**	**GROUP 4**
dgm	af	Tac	Qls
gn	Q*, Q**	TQjhc	
gr	Tab, Tar		
grc	Taw, Tp		
grd	Tpb, Tpcg		
gr-m	Tps, Tpv		
gru	TQjh, TQjha		
hd	TQjhb, TQjhcs		
hdg	TQjhf, TQjhm		
hqm	TQjhp, TQjhr		
lgd	TQjhs		
lgdb	TQjhsb		
m, ms	TQjhv		
sqd	Tsf, Tfsc		
	Tsfl, Tva		
	Tvts, Tvv		

Table 2.2. Summary of Shear Strength Groups for the Juniper Hills Quadrangle.

PART II

EARTHQUAKE-INDUCED LANDSLIDE HAZARD POTENTIAL

Design Strong-Motion Record

To evaluate earthquake-induced landslide hazard potential in the study area, a method of dynamic slope stability analysis developed by Newmark (1965) was used. The Newmark method analyzes dynamic slope stability by calculating the cumulative down-slope displacement for a given earthquake strong-motion time history. As implemented for the preparation of earthquake-induced landslide zones, the Newmark method necessitates the selection of a design earthquake strong-motion record to provide the "ground shaking opportunity". For the Juniper Hills Quadrangle, selection of a strong motion record was based on an estimation of probabilistic ground motion parameters for modal magnitude, modal distance, and peak ground acceleration (PGA). The parameters were estimated from maps prepared by DMG for a 10 percent probability of being exceeded in 50 years (Petersen and others, 1996). The parameters used in the record selection are:

Modal Magnitude:	7.6 to 7.8
Modal Distance:	2.6 to 12.3 km
PGA:	0.54g to 0.91g

The strong-motion record selected for the slope stability analysis in the Juniper Hills Quadrangle was the Southern California Edison (SCE) Lucerne record from the 1992 magnitude 7.3 Landers, California, earthquake. This record had a source to recording site distance of 1.1 km and a peak ground acceleration (PGA) of 0.80g. Although the magnitude and PGA values of the Lucerne record do not fall within the range of the probabilistic parameters, this record was considered to be sufficiently conservative to be used in the stability analyses. The selected strong-motion record was not scaled or otherwise modified prior to its use in the analysis.

Displacement Calculation

The design strong-motion record was used to develop a relationship between landslide displacement and yield acceleration (a_y), defined as the earthquake horizontal ground acceleration above which landslide displacements take place. This relationship was prepared by integrating the design strong-motion record twice for a given acceleration value to find the corresponding displacement, and the process was repeated for a range of acceleration values (Jibson, 1993). The resulting curve in Figure 2.1 represents the full spectrum of displacements that can be expected for the design strong-motion record. This curve provides the required link between anticipated earthquake shaking and estimates of displacement for different combinations of geologic materials and slope gradient, as described in the Slope Stability Analysis section below.

The amount of displacement predicted by the Newmark analysis provides an indication of the relative amount of damage that could be caused by earthquake-induced landsliding. Displacements of 30, 15 and 5 cm are used as criteria for rating levels of earthquake-induced landslide hazard potential based on the work of Youd (1980), Wilson and Keefer (1983), and the CGS pilot study for earthquake-induced landslides (McCrink and Real, 1996; McCrink, 2001). Applied to the curve in Figure 2.1, these displacements correspond to yield accelerations of 0.14, 0.18, and 0.24 g. Because these yield acceleration values are derived from the design strong-motion record, they represent the ground shaking opportunity thresholds that are significant to the Juniper Hills Quadrangle.

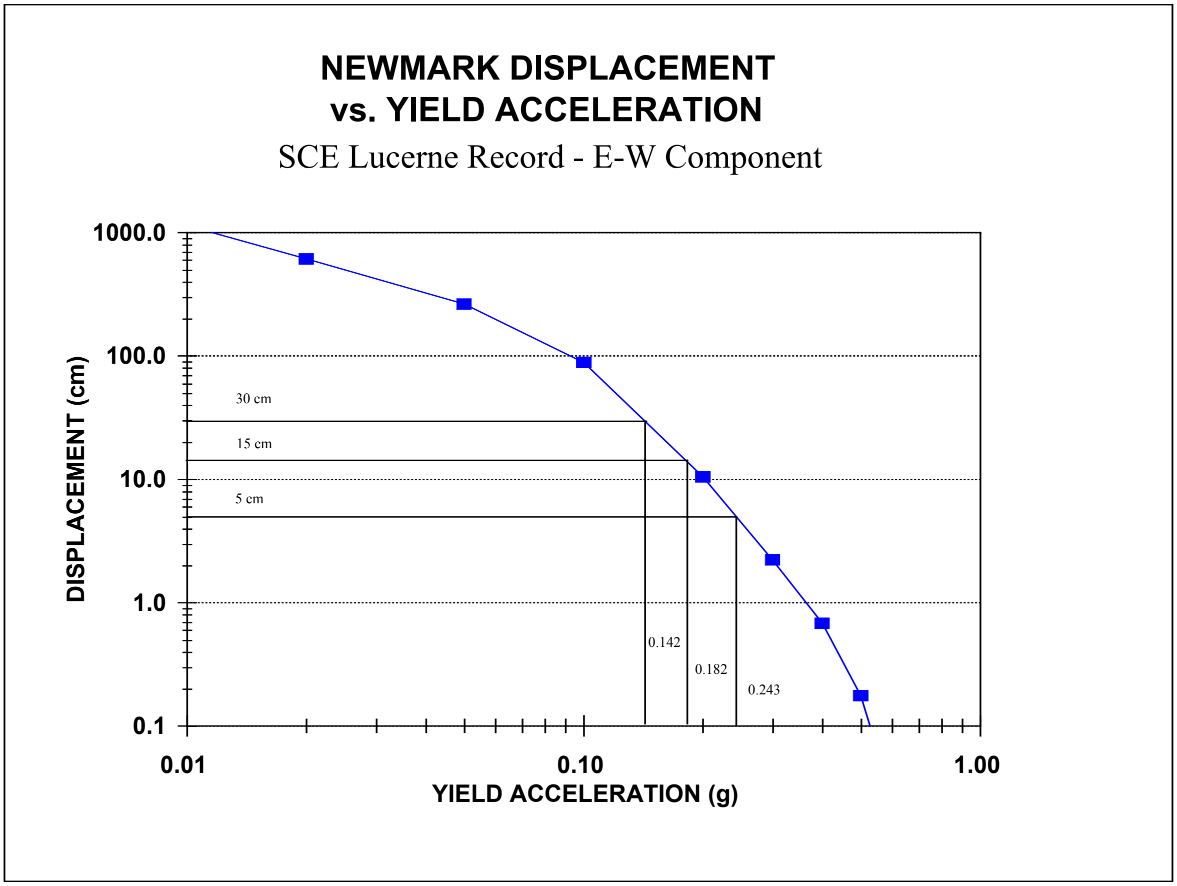

Figure 2.1. Yield Acceleration vs. Newmark Displacement for the 1992 Landers Earthquake SCE Lucerne Record.

Slope Stability Analysis

A slope stability analysis was performed for each geologic material strength group at slope increments of 1 degree. An infinite-slope failure model under unsaturated slope conditions was assumed. A factor of safety was calculated first, followed by calculation of yield acceleration from Newmark's equation:

$$a_y = (FS - 1)g \sin \alpha$$

where FS is the Factor of Safety, g is the acceleration due to gravity, and α is the direction of movement of the slide mass, in degrees measured from the horizontal, when displacement is initiated (Newmark, 1965). For an infinite slope failure, α is the same as the slope angle.

The yield accelerations resulting from Newmark's equations represent the susceptibility to earthquake-induced failure of each geologic material strength group for a range of slope gradients. Based on the relationship between yield acceleration and Newmark displacement shown in Figure 2.1, hazard potentials were assigned as follows:

1. If the calculated yield acceleration was less than 0.14g, Newmark displacement greater than 30 cm is indicated, and a HIGH hazard potential was assigned.
2. Likewise, if the calculated yield acceleration fell between 0.14g and 0.18g, Newmark displacement between 15 cm and 30 cm is indicated, and a MODERATE hazard potential was assigned.
3. If the calculated yield acceleration fell between 0.18g and 0.24g, Newmark displacement between 5 cm and 15 cm is indicated, and a LOW hazard potential was assigned.
4. If the calculated yield acceleration was greater than 0.24g, Newmark displacement of less than 5 cm is indicated, and a VERY LOW potential was assigned.

Table 2.3 summarizes the results of the stability analyses. The earthquake-induced landslide hazard potential map was prepared by combining the geologic material-strength map and the slope map according to this table.

JUNIPER HILLS QUADRANGLE HAZARD POTENTIAL MATRIX				
Geologic Material Strength Group (Average Phi)	HAZARD POTENTIAL (Percent Slope)			
	Very Low	Low	Moderate	High
1 (35)	0 to 44%	44 to 50%	50 to 55%	>55%
2 (30)	0 to 32	32 to 38	38 to 42	>42%
3 (26)	0 to 24	24 to 30%	30 to 34%	>34%
4 (16)	0 to 5%	5 to 10%	10 to 15%	>15%

Table 2.3. Hazard Potential Matrix for Earthquake-Induced Landslides in the Juniper Hills Quadrangle. Values in the table show the range of slope gradient (expressed as percent slope) corresponding to calculated Newmark displacement ranges from the design earthquake for each material strength group.

EARTHQUAKE-INDUCED LANDSLIDE HAZARD ZONE

Criteria for Zoning

Earthquake-induced landslide zones were delineated using criteria adopted by the California State Mining and Geology Board (DOC, 2000). Under these criteria, earthquake-induced landslide hazard zones are defined as areas that meet one or both of the following conditions:

1. Areas that have been identified as having experienced landslide movement in the past, including all mappable landslide deposits and source areas as well as any landslide that is known to have been triggered by historic earthquake activity.
2. Areas where the geologic and geotechnical data and analyses indicate that the earth materials may be susceptible to earthquake-induced slope failure.

These conditions are discussed in further detail in the following sections.

Existing Landslides

Existing landslides typically consist of disrupted soils and rock materials that are generally weaker than adjacent undisturbed rock and soil materials. Previous studies indicate that existing landslides can be reactivated by earthquake movements (Keefer, 1984). Earthquake-triggered movement of existing landslides is most pronounced in steep head scarp areas and at the toe of existing landslide deposits. Although reactivation of deep-seated landslide deposits is less common (Keefer, 1984), a significant number of deep-seated landslide movements have occurred during, or soon after, several recent earthquakes. **Based on these observations, all existing landslides with a definite or probable confidence rating are included within the earthquake-induced landslide hazard zone.**

Geologic and Geotechnical Analysis

Based on the conclusions of a pilot study performed by CGS (McCrink and Real, 1996; McCrink, 2001), it has been concluded that earthquake-induced landslide hazard zones should encompass all areas that have a High, Moderate or Low level of hazard potential (see Table 2.3). This would include all areas where the analyses indicate earthquake displacements of 5 centimeters or greater. Areas with a Very Low hazard potential, indicating less than 5 centimeters displacement, are excluded from the zone.

As summarized in Table 2.3, all areas characterized by the following geologic strength group and slope gradient conditions are included in the earthquake-induced landslide hazard zone:

1. Geologic Strength Group 4 is included for all slopes steeper than 5 percent. (Note: The only geologic unit included in Geologic Strength Group 5 is Qls, existing landslides. They have been included or excluded from the landslide zones on the basis of the criteria described in the previous section).

2. Geologic Strength Group 3 is included for all slopes steeper than 24 percent.

3. Geologic Strength Group 2 is included for all slopes steeper than 32 percent.

4. Geologic Strength Group 1 is included for all slopes steeper than 44 percent.

This results in 4.6 percent of the entire quadrangle and 9 percent of the study area lying within the earthquake-induced landslide hazard zone for the Juniper Hills Quadrangle.

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APPENDIX A
SOURCE OF ROCK STRENGTH DATA

SOURCE	NUMBER OF TESTS SELECTED
Los Angeles County	**34**
Ritter Ridge Quadrangle	**78**
Palmdale Quadrangle	**20**
Littlerock Quadrangle	**20**
Valyermo Quadrangle	**5**
Total Number of Shear Tests	**157**

SECTION 3
GROUND SHAKING EVALUATION REPORT

Potential Ground Shaking in the Juniper Hills 7.5-Minute Quadrangle, Los Angeles County, California

By

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California Department of Conservation
California Geological Survey
***Formerly with CGS, now with U.S. Geological Survey**

PURPOSE

The Seismic Hazards Mapping Act (the Act) of 1990 (Public Resources Code, Chapter 7.8, Division 2) directs the California Department of Conservation (DOC), Division of Mines and Geology (DMG) [now called California Geological Survey (CGS)] to delineate Seismic Hazard Zones. The purpose of the Act is to reduce the threat to public health and safety and to minimize the loss of life and property by identifying and mitigating seismic hazards. Cities, counties, and state agencies are directed to use the Seismic Hazard Zone Maps in their land-use planning and permitting processes. The Act requires that site-specific geotechnical investigations be performed prior to permitting most urban development projects within the hazard zones. Evaluation and mitigation of seismic hazards are to be conducted under guidelines established by the California State Mining and Geology Board (DOC, 1997). The text of this report is on the Internet at http://gmw.consrv.ca.gov/shmp/SHMPsp117.asp

This section of the evaluation report summarizes the ground motions used to evaluate liquefaction and earthquake-induced landslide potential for zoning purposes. Included are ground motion and related maps, a brief overview on how these maps were prepared, precautionary notes concerning their use, and related references. The maps provided herein are presented at a scale of approximately 1:150,000 (scale bar provided on maps), and show the full 7.5-minute quadrangle and portions of the adjacent eight quadrangles. They can be used to assist in the specification of earthquake loading conditions ***for the analysis of ground failure*** according to the "Simple Prescribed Parameter Value" method (SPPV) described in the site investigation guidelines (DOC, 1997). Alternatively, they can be used as a basis for comparing levels of ground motion determined by other methods with the statewide standard.

This section and Sections 1 and 2 (addressing liquefaction and earthquake-induced landslide hazards) constitute a report series that summarizes development of seismic hazard zone maps in the state. Additional information on seismic hazard zone mapping in California can be accessed on the California Geological Survey's Internet page: http://www.consrv.ca.gov/CGS/index.htm

EARTHQUAKE HAZARD MODEL

The estimated ground shaking is derived from the statewide probabilistic seismic hazard evaluation released cooperatively by the California Department of Conservation, Division of Mines and Geology [California Geological Survey], and the U.S. Geological Survey (Petersen and others, 1996). That report documents an extensive 3-year effort to obtain consensus within the scientific community regarding fault parameters that characterize the seismic hazard in California. Fault sources included in the model were evaluated for long-term slip rate, maximum earthquake magnitude, and rupture geometry. These fault parameters, along with historical seismicity, were used to estimate return times of moderate to large earthquakes that contribute to the hazard.

The ground shaking levels are estimated for each of the sources included in the seismic source model using attenuation relations that relate earthquake shaking with magnitude, distance from the earthquake, and type of fault rupture (strike-slip, reverse, normal, or subduction). The published hazard evaluation of Petersen and others (1996) only considers uniform firm-rock site conditions. In this report, however, we extend the hazard analysis to include the hazard of exceeding peak horizontal ground acceleration (PGA) at 10 percent probability of exceedance in 50 years on spatially uniform conditions of rock, soft rock, and alluvium. These soil and rock conditions approximately correspond to site categories defined in Chapter 16 of the Uniform Building Code (ICBO, 1997), which are commonly found in California. We use the attenuation relations of Boore and others (1997), Campbell (1997), Sadigh and others (1997), and Youngs and others (1997) to calculate the ground motions.

The seismic hazard maps for ground shaking are produced by calculating the hazard at sites separated by about 5 km. Figures 3.1 through 3.3 show the hazard for PGA at 10 percent probability of exceedance in 50 years assuming the entire map area is firm rock, soft rock, or alluvial site conditions respectively. The sites where the hazard is calculated are represented as dots and ground motion contours as shaded regions. The quadrangle of interest is outlined by bold lines and centered on the map. Portions of the eight

JUNIPER HILLS 7.5 MINUTE QUADRANGLE AND PORTIONS OF
ADJACENT QUADRANGLES

10% EXCEEDANCE IN 50 YEARS PEAK GROUND ACCELERATION (g)

1998

FIRM ROCK CONDITIONS

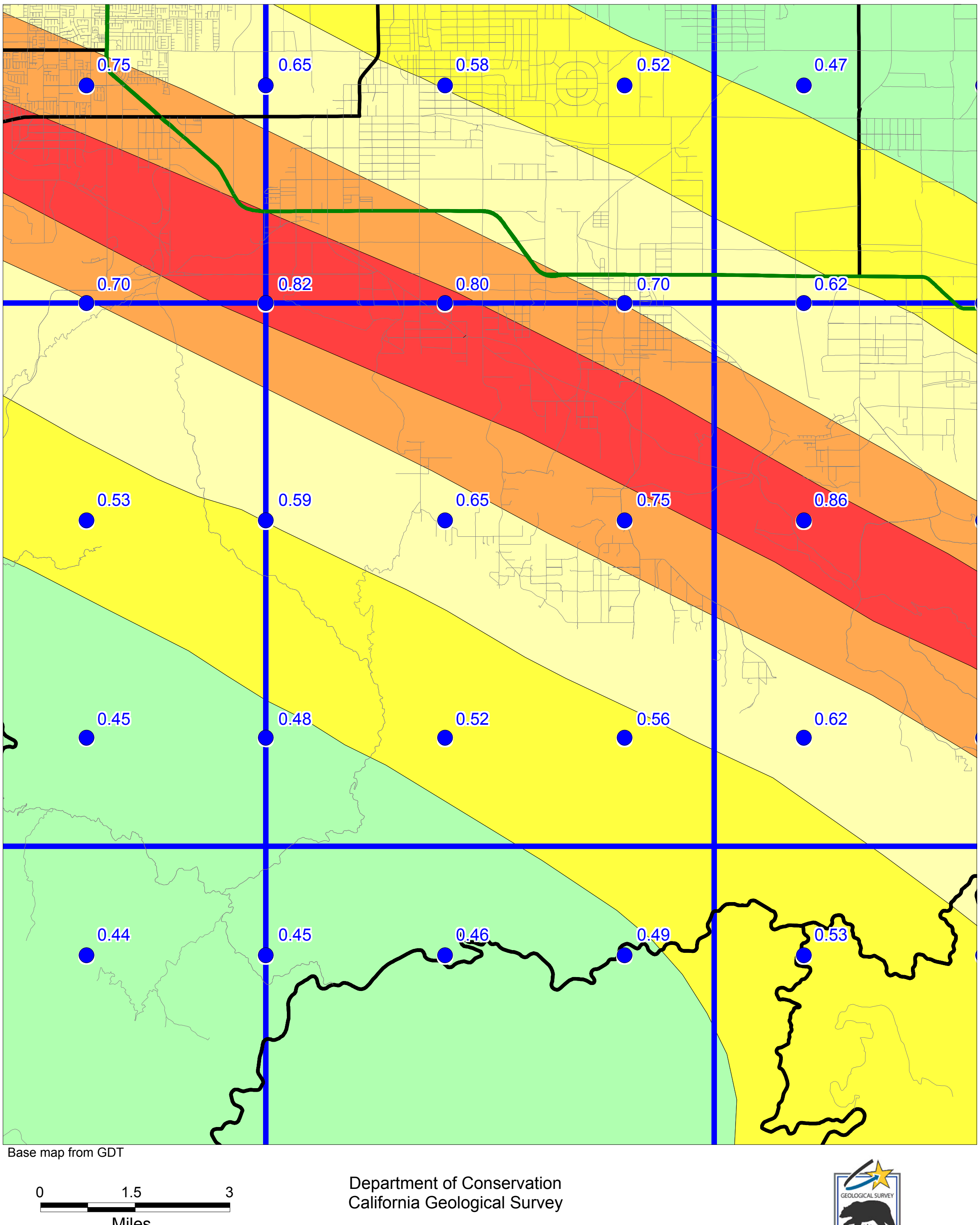

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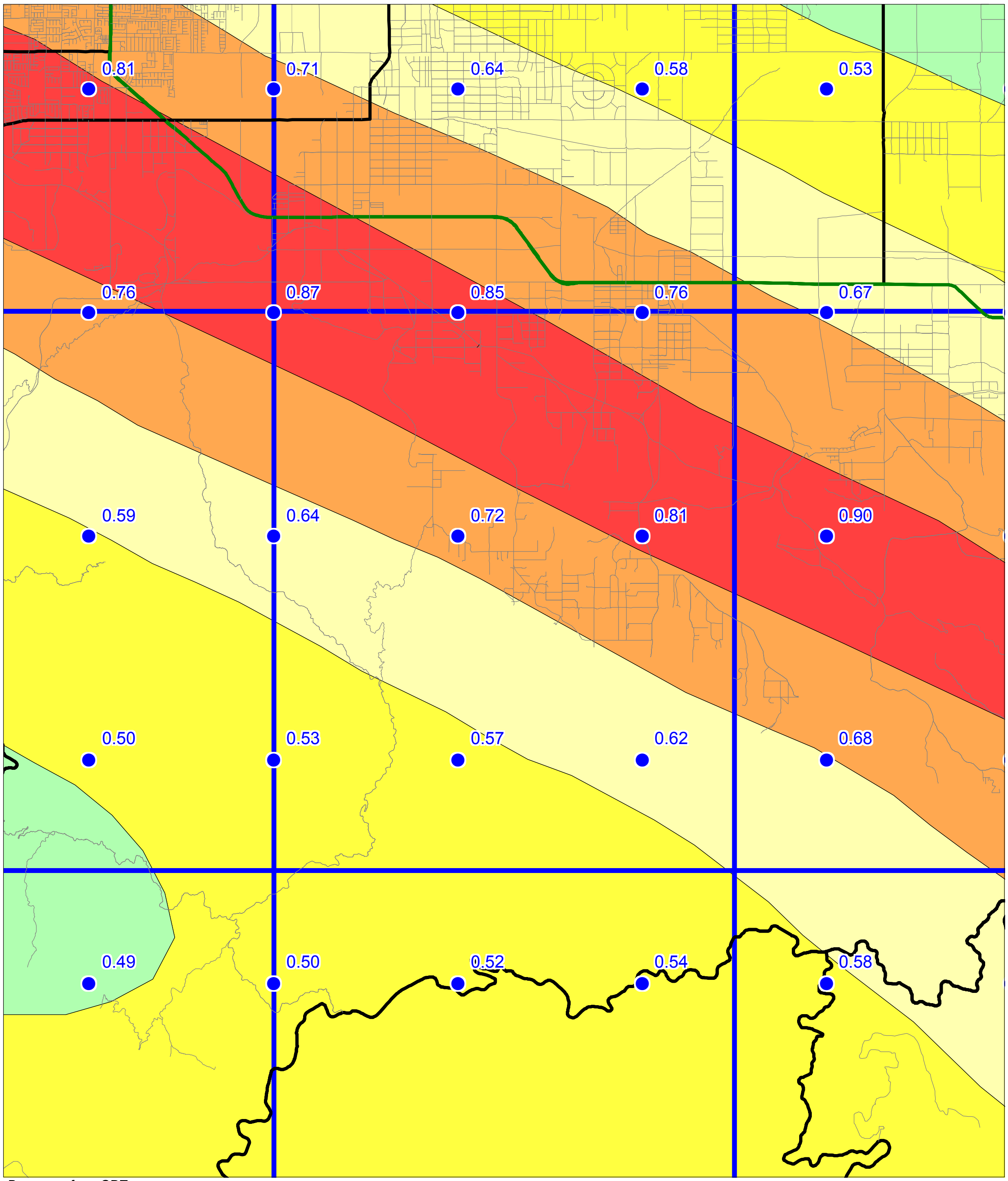
Figure 3.1

JUNIPER HILLS 7.5 MINUTE QUADRANGLE AND PORTIONS OF ADJACENT QUADRANGLES

10% EXCEEDANCE IN 50 YEARS PEAK GROUND ACCELERATION (g)

1998

SOFT ROCK CONDITIONS



Base map from GDT

0 1.5 3
Miles

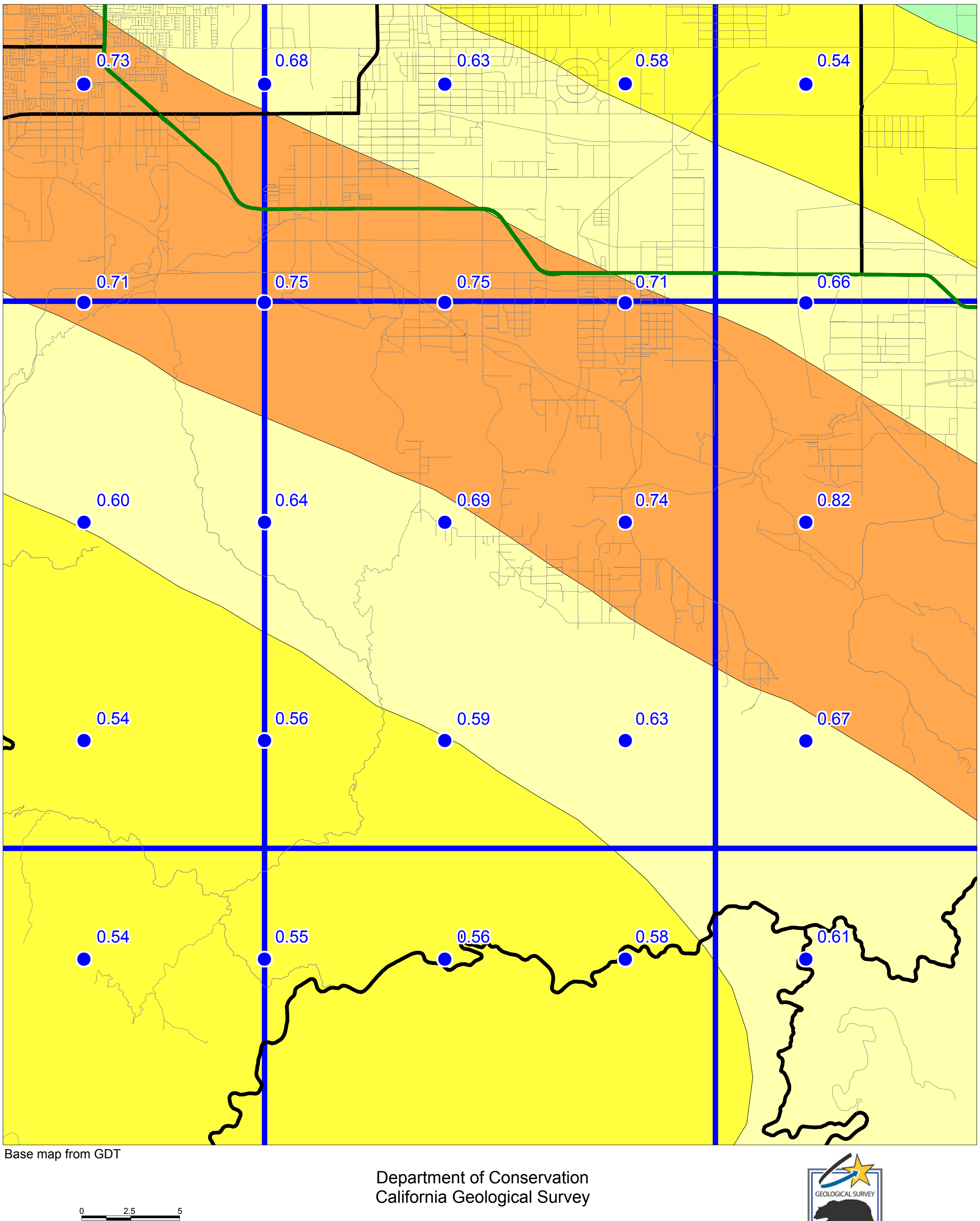
Department of Conservation
California Geological Survey

Figure 3.2

JUNIPER HILLS 7.5 MINUTE QUADRANGLE AND PORTIONS OF ADJACENT QUADRANGLES

10% EXCEEDANCE IN 50 YEARS PEAK GROUND ACCELERATION (g)
1998

ALLUVIUM CONDITIONS



Department of Conservation
California Geological Survey

Figure 3.3

adjacent quadrangles are also shown so that the trends in the ground motion may be more apparent. We recommend estimating ground motion values by selecting the map that matches the actual site conditions, and interpolating from the calculated values of PGA rather than the contours, since the points are more accurate.

APPLICATIONS FOR LIQUEFACTION AND LANDSLIDE HAZARD ASSESSMENTS

Deaggregation of the seismic hazard identifies the contribution of each of the earthquakes (various magnitudes and distances) in the model to the ground motion hazard for a particular exposure period (see Cramer and Petersen, 1996). The map in Figure 3.4 identifies the magnitude and the distance (value in parentheses) of the earthquake that contributes most to the hazard at 10 percent probability of exceedance in 50 years on alluvial site conditions (*predominant earthquake*). This information gives a rationale for selecting a seismic record or ground motion level in evaluating ground failure. However, it is important to keep in mind that more than one earthquake may contribute significantly to the hazard at a site, and those events can have markedly different magnitudes and distances. For liquefaction hazard the predominant earthquake magnitude from Figure 3.4 and PGA from Figure 3.3 (alluvium conditions) can be used with the Youd and Idriss (1997) approach to estimate cyclic stress ratio demand. For landslide hazard the predominant earthquake magnitude and distance can be used to select a seismic record that is consistent with the hazard for calculating the Newmark displacement (Wilson and Keefer, 1983). When selecting the predominant earthquake magnitude and distance, it is advisable to consider the range of values in the vicinity of the site and perform the ground failure analysis accordingly. This would yield a range in ground failure hazard from which recommendations appropriate to the specific project can be made. Grid values for predominant earthquake magnitude and distance should **not** be interpolated at the site location, because these parameters are not continuous functions.

A preferred method of using the probabilistic seismic hazard model and the “simplified Seed-Idriss method” of assessing liquefaction hazard is to apply magnitude scaling probabilistically while calculating peak ground acceleration for alluvium. The result is a “magnitude-weighted” ground motion (liquefaction opportunity) map that can be used directly in the calculation of the cyclic stress ratio threshold for liquefaction and for estimating the factor of safety against liquefaction (Youd and Idriss, 1997). This can provide a better estimate of liquefaction hazard than use of predominate magnitude described above, because all magnitudes contributing to the estimate are used to weight the probabilistic calculation of peak ground acceleration (Real and others, 2000). Thus, large distant earthquakes that occur less frequently but contribute *more* to the liquefaction hazard are appropriately accounted for.

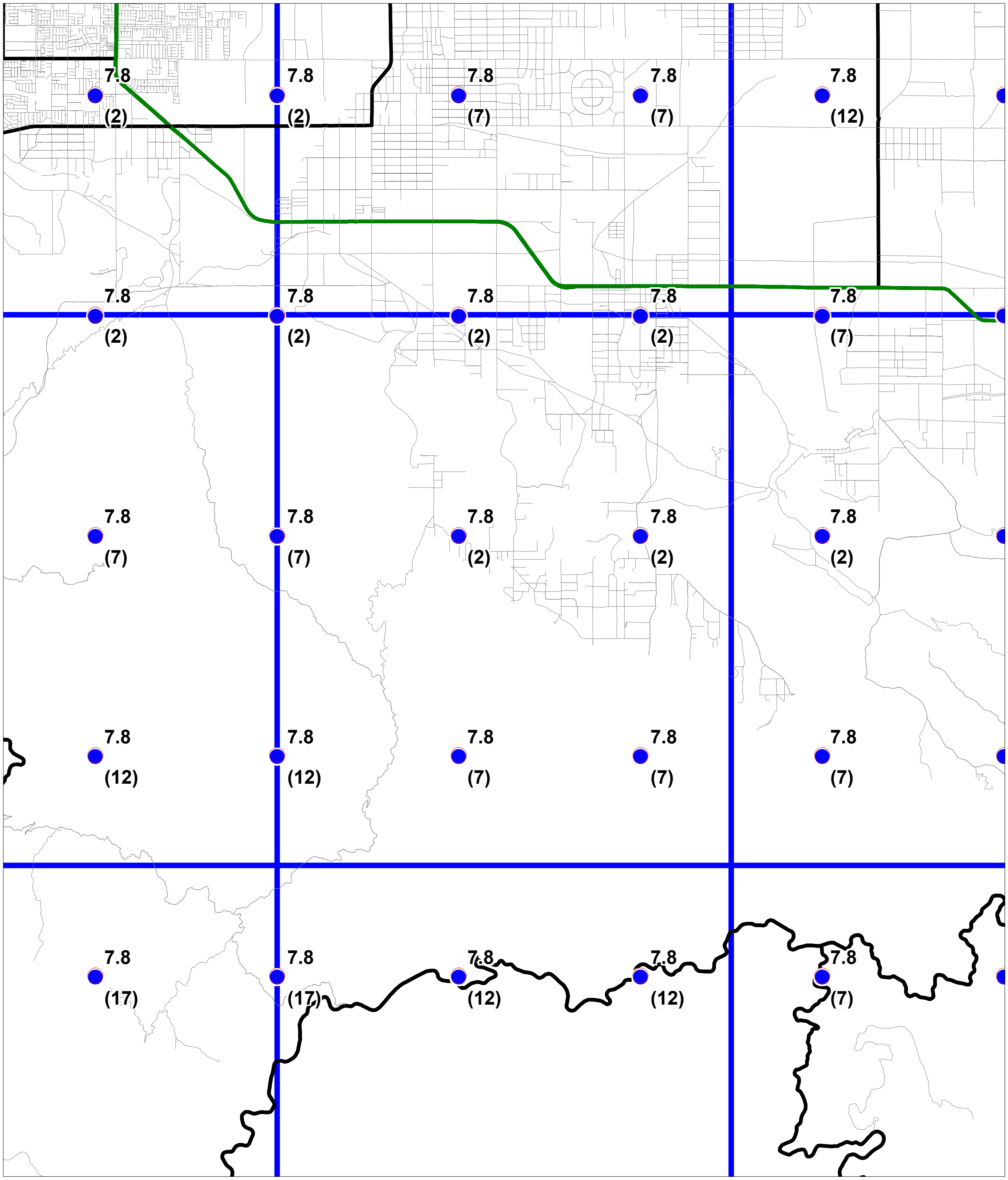
Figure 3.5 shows the magnitude-weighted alluvial PGA based on Idriss’ weighting function (Youd and Idriss, 1997). It is important to note that the values obtained from this map are pseudo-accelerations and should be used in the formula for factor of safety without any magnitude-scaling (a factor of 1) applied.

JUNIPER HILLS 7.5 MINUTE QUADRANGLE AND PORTIONS OF ADJACENT QUADRANGLES

10% EXCEEDANCE IN 50 YEARS PEAK GROUND ACCELERATION

1998

PREDOMINANT EARTHQUAKE
Magnitude (Mw)
(Distance (km))



Base map from GDT

0 1.5 3
Miles

Department of Conservation
California Geological Survey

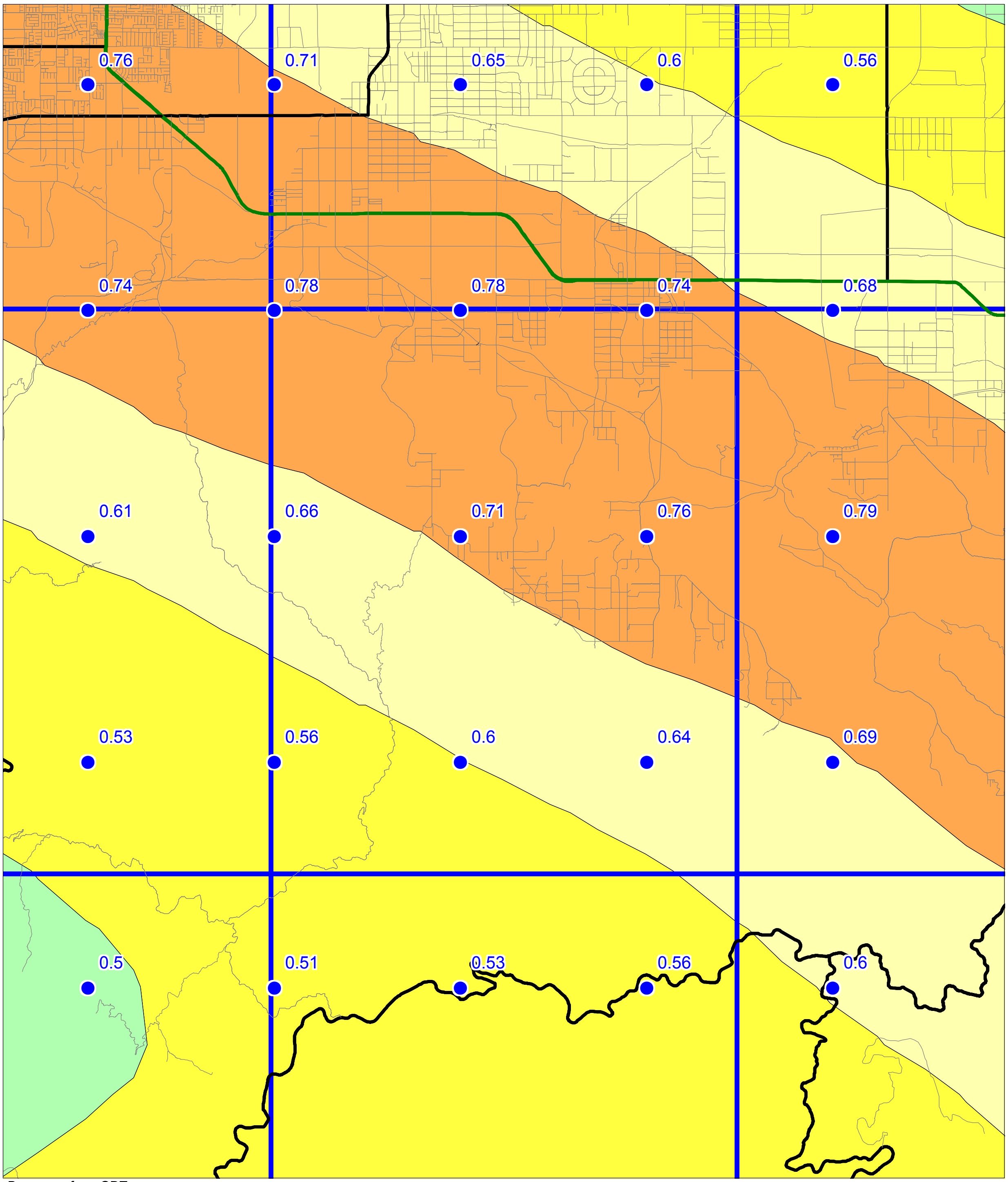
Figure 3.4

JUNIPER HILLS 7.5 MINUTE QUADRANGLE AND PORTIONS OF ADJACENT QUADRANGLES

10% EXCEEDANCE IN 50 YEARS MAGNITUDE-WEIGHTED PSEUDO-PEAK ACCELERATION (g) FOR ALLUVIUM

1998

LIQUEFACTION OPPORTUNITY



Base map from GDT

0 1.5 3

Miles

Department of Conservation
California Geological Survey

Figure 3.5

USE AND LIMITATIONS

The statewide map of seismic hazard has been developed using regional information and is ***not appropriate for site specific structural design applications***. Use of the ground motion maps prepared at larger scale is limited to estimating earthquake loading conditions for preliminary assessment of ground failure at a specific location. We recommend consideration of site-specific analyses before deciding on the sole use of these maps for several reasons.

1. The seismogenic sources used to generate the peak ground accelerations were digitized from the 1:750,000-scale fault activity map of Jennings (1994). Uncertainties in fault location are estimated to be about 1 to 2 kilometers (Petersen and others, 1996). Therefore, differences in the location of calculated hazard values may also differ by a similar amount. At a specific location, however, the log-linear attenuation of ground motion with distance renders hazard estimates less sensitive to uncertainties in source location.
2. The hazard was calculated on a grid at sites separated by about 5 km (0.05 degrees). Therefore, the calculated hazard may be located a couple kilometers away from the site. We have provided shaded contours on the maps to indicate regional trends of the hazard model. However, the contours only show regional trends that may not be apparent from points on a single map. Differences of up to 2 km have been observed between contours and individual ground acceleration values. *We recommend that the user interpolate PGA between the grid point values rather than simply using the shaded contours*.
3. Uncertainties in the hazard values have been estimated to be about +/- 50 percent of the ground motion value at two standard deviations (Cramer and others, 1996).
4. Not all active faults in California are included in this model. For example, faults that do not have documented slip rates are not included in the source model. Scientific research may identify active faults that have not been previously recognized. Therefore, future versions of the hazard model may include other faults and omit faults that are currently considered.
5. A map of the predominant earthquake magnitude and distance is provided from the deaggregation of the probabilistic seismic hazard model. However, it is important to recognize that a site may have more than one earthquake that contributes significantly to the hazard. Therefore, in some cases earthquakes other than the predominant earthquake should also be considered.

Because of its simplicity, it is likely that the SPPV method (DOC, 1997) will be widely used to estimate earthquake shaking loading conditions for the evaluation of ground failure hazards. It should be kept in mind that ground motions at a given distance from an earthquake will vary depending on site-specific characteristics such as geology, soil properties, and topography, which may not have been adequately accounted for in the regional hazard analysis. Although this variance is represented to some degree by the recorded ground motions that form the basis of the hazard model used to produce Figures 3.1, 3.2, and 3.3, extreme deviations can occur. More sophisticated methods that take into account other factors that may be present at the site (site amplification, basin effects, near source effects, etc.) should be employed as warranted. The decision to use the SPPV method with ground motions derived from Figures 3.1, 3.2, or 3.3 should be based on careful consideration of the above limitations, the geotechnical and seismological aspects of the project setting, and the "importance" or sensitivity of the proposed building with regard to occupant safety.

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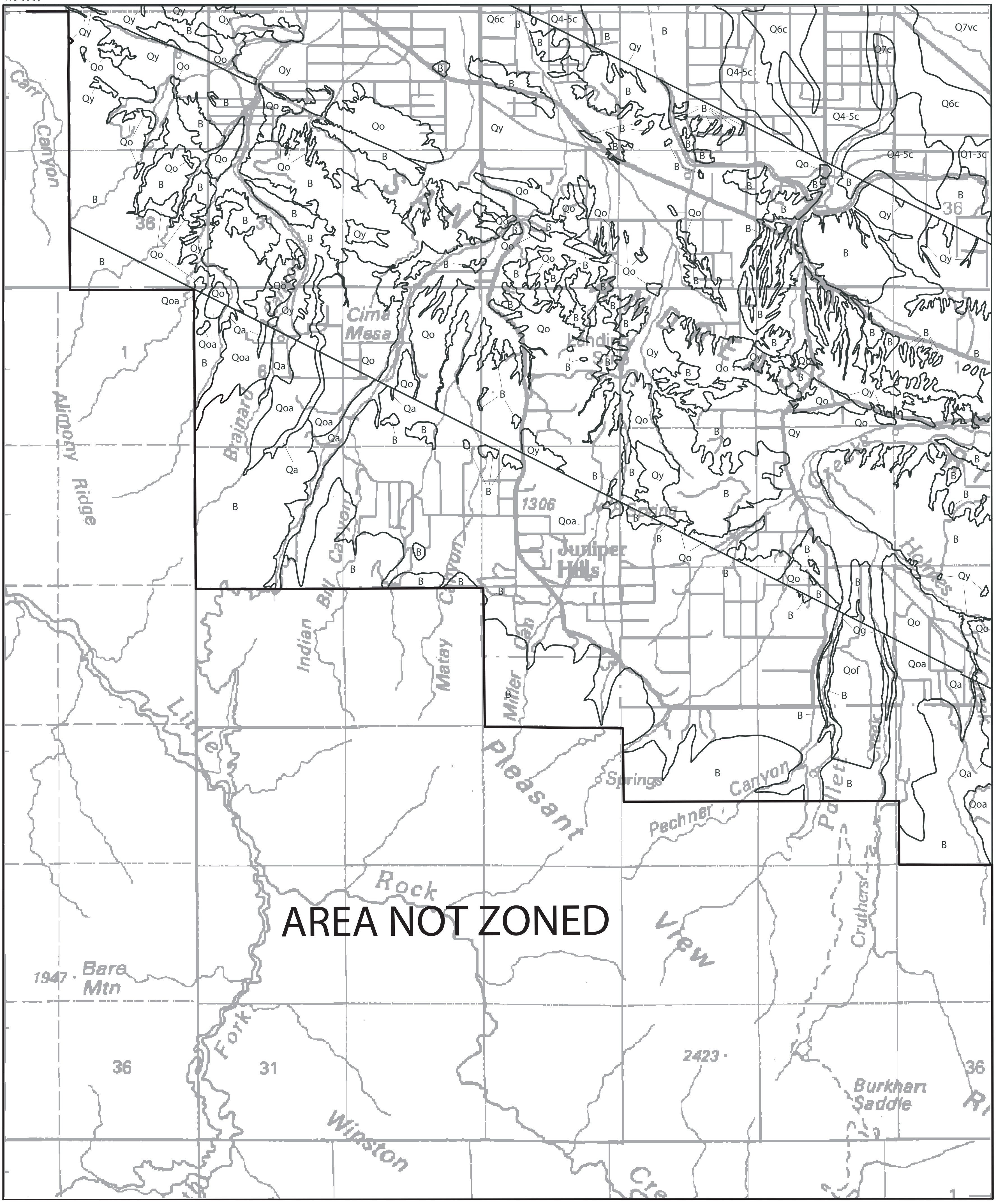
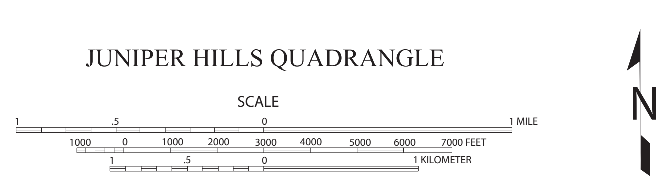
118°00'00"
34°30'00"

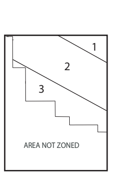


34°22'30"
117°52'30"

Base map enlarged from U.S.G.S. 30 x 60-minute series

JUNIPER HILLS QUADRANGLE





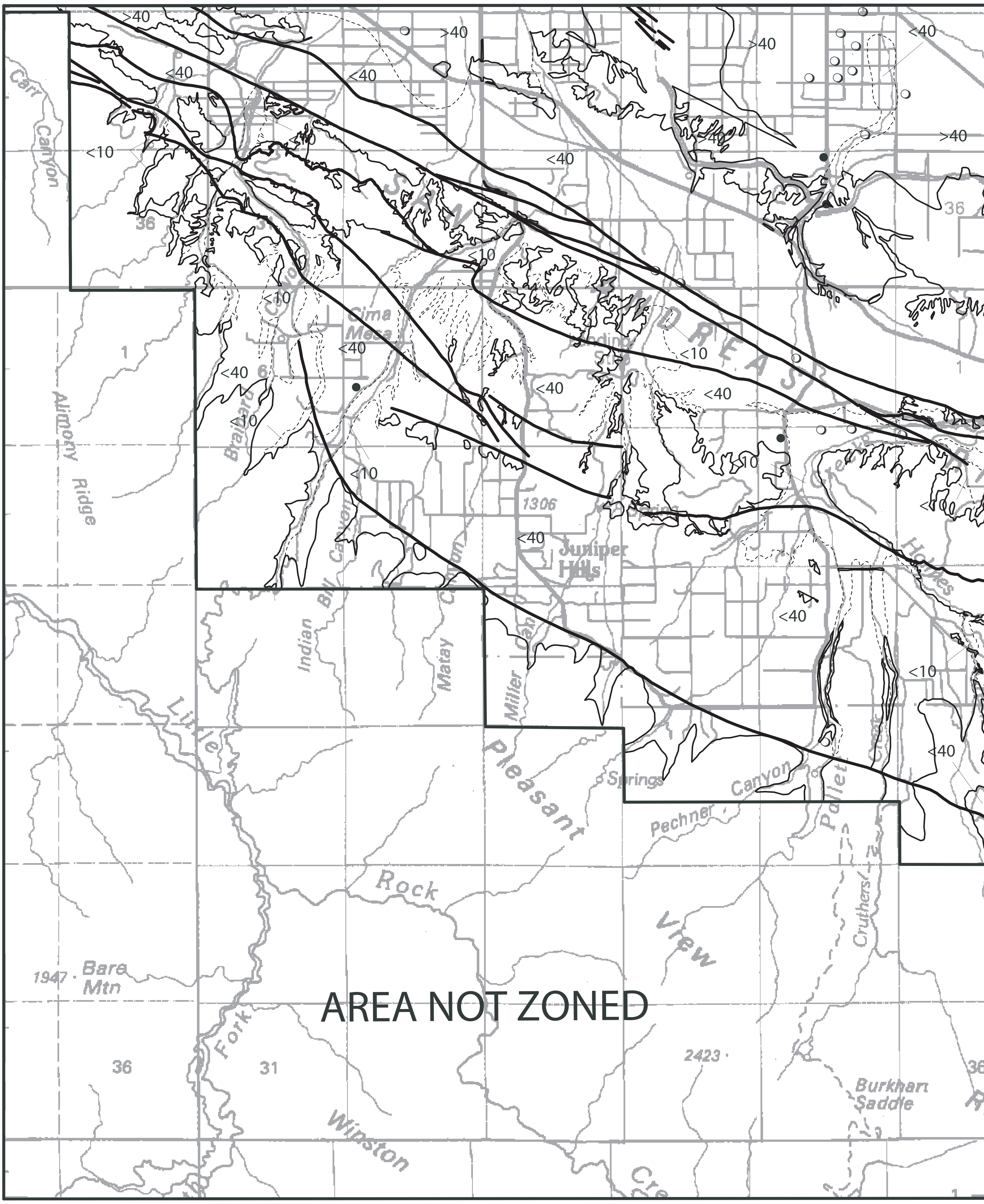
Explanation

Northern, central, and southern map sections are modified from Ponti and Burke (1980) (1), Barrows and others (1985) (2), and Dibblee (2002) (3), respectively.

Note: For reasons of scale, all older Quaternary units and younger Quaternary units of Barrows and others (1985) have been combined into Qo and Qy, respectively.

Plate 1.1. Quaternary Geologic Materials Map of part of the Juniper Hills 7.5-Minute Quadrangle, California.

118°00'00"
34°30'00"



34°22'30"
117°52'30"

Base map enlarged from U.S.G.S. 30 x 60-minute series

JUNIPER HILLS QUADRANGLE

SCALE

Explanation

Areas shaded gray: Quaternary alluvium.
Areas not shaded: Pre-Quaternary bedrock.

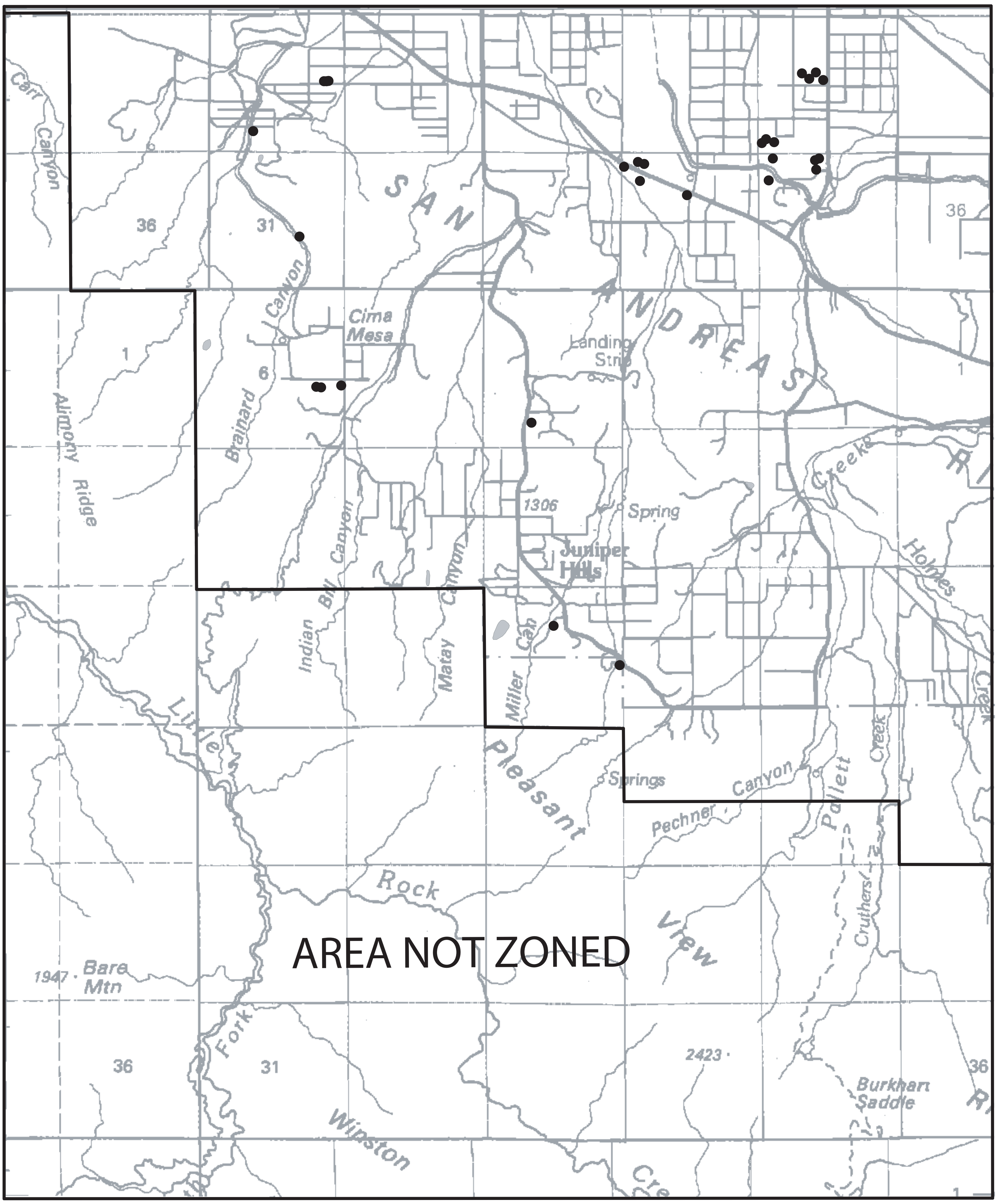
Major faults along the San Andreas Rift Zone

<40 Depth to historically shallowest ground water, in feet
(Note: Dotted lines enclose areas where depth to ground water has historically been less than it has been in surrounding areas)

Map Symbols

- Geotechnical boring site
- Water well site
- Liquefaction sandboil features related to paleoseismic events (Pallett Creek)

Plate 1.2. Depth to historically shallowest ground water and locations of boreholes used in this study, Juniper Hills 7.5-Minute Quadrangle, California.



Base map enlarged from U.S.G.S. 30 x 60-minute series

JUNIPER HILLS QUADRANGLE

SCALE
1 .5 0 1 MILE
1000 0 2000 4000 6000 FEET
1 .5 0 1 KILOMETER

N

● Shear test sample location

Landslide

Plate 2.1 Landslide inventory, and shear test sample locations, Juniper Hills 7.5-Minute Quadrangle, California.